Communicating Warfighting Requirements to Systems Engineers, Part II

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25 February 2002

Requirements Definition	Conceptual Model Development	Design Development	Integration & Testing	Execution & Results Analysis

System Purpose
User Interactions

Mission Operations
Human Behavior

Physical Sciences
Environment

System Engineering
Hardware Configuration

Software Engineering
Software Architecture

Language, DBMS
Style Guidelines

Federation, Scenarios
Parametric Data


End Users


Warfighters


Scientists


Analysts

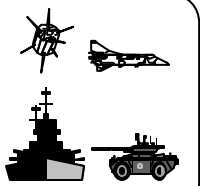

Designers


Programmers


Controllers

Data Standards

Quality Engineering



User Space Model

Mission Space Model

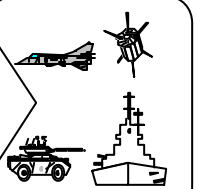
C&P Spec's

System Analysis Model

Logical Design Model

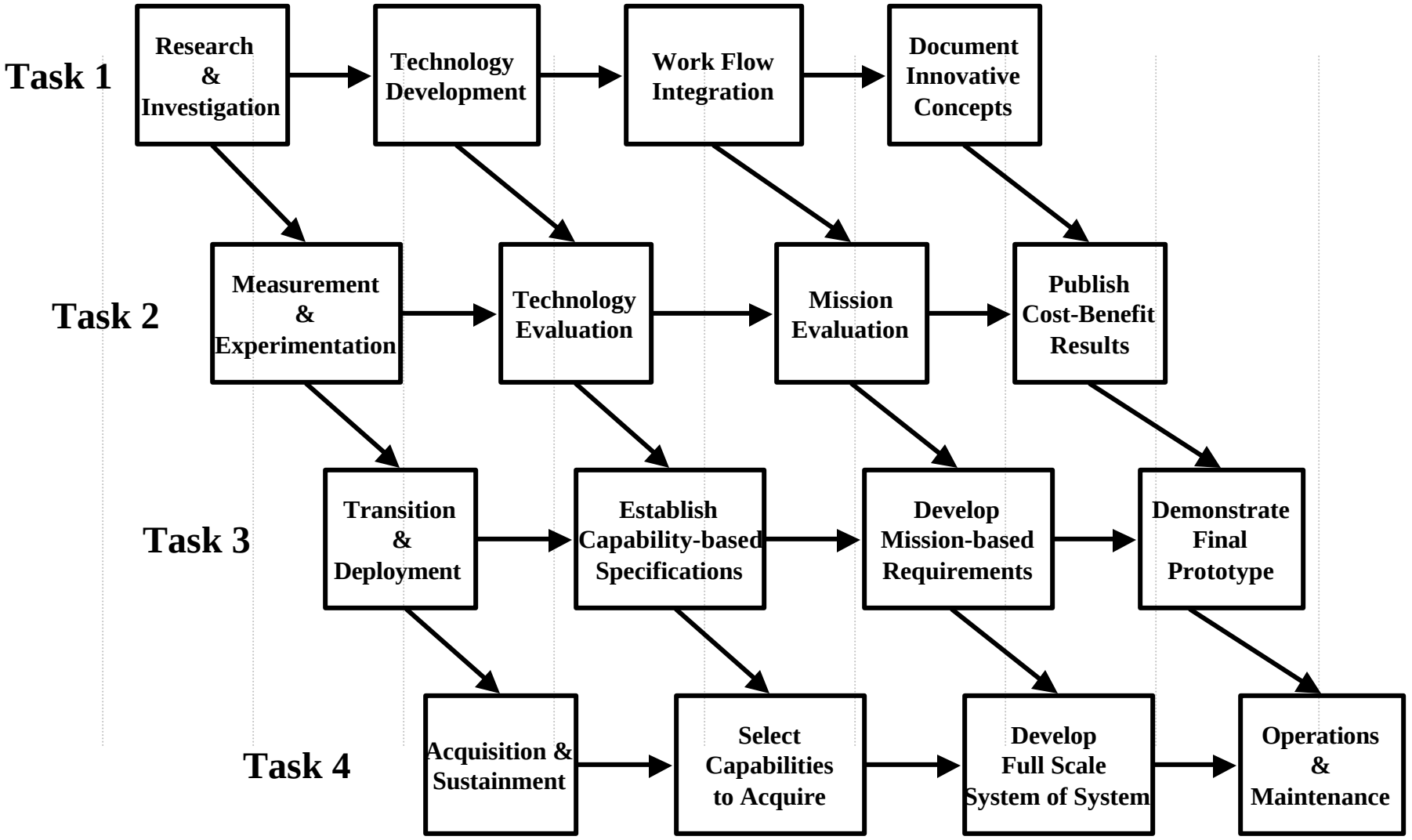
S/W

Exercise Model



Real World — Knowledge Acquisition — Front end Analysis — Application Development — Simulated World

Product Work Flow



Methodology (Part 1 of 3)
Generate a Level 4] Scenario

1) Create road-to-war to provide mission context.

2) Select an organizing principle for Combat Interactions.

3) Use hierarchical Strategy-to-Mission-to-Task (S-M-T) decomposition to organize the Combat Processes.

4) Use hierarchical Order-of-Battle decomposition to complete assignment of Task-Organized forces to Combat Processes.

5) Establish Task-based fault tree for Mission success using Measures, Conditions, and Standards for desired End-States.

6) Construct integrated Use-Case-Threads to sequence execution of Combat Processes leading to Combat Interactions.

Methodology (Part 3 of 3)
Express Warfighting Utility

9) Warfighting utility is then expressed in terms of how the noted outcomes either enable or constrain Task execution within a Mission context.

* Resounding victory in many (but not enough) branches may not lead to overall Mission success; conversely, resounding defeat in many (but not critical) branches may still lead to overall Mission success.

* Task execution becomes as much a measurable outcome as MOP and MOE of entities and can be traced for cause and effect.

* We are exploring the mathematical relationships between entity and task with the idea that they may be described by a transform yet to be derived.

Methodology (Part 2 of 3)
Compute Level 4] Effectiveness from Level 3] Performance

7) Compute Measures (of performance), under prescribed Conditions, and compare to Task-based fault tree Standards to determine the Mission outcome of a Combat Process following a Combat Interaction.

8) Determine affects on other Combat Processes. Affects can be one of three kinds:

First, a direct input to a subsequent task

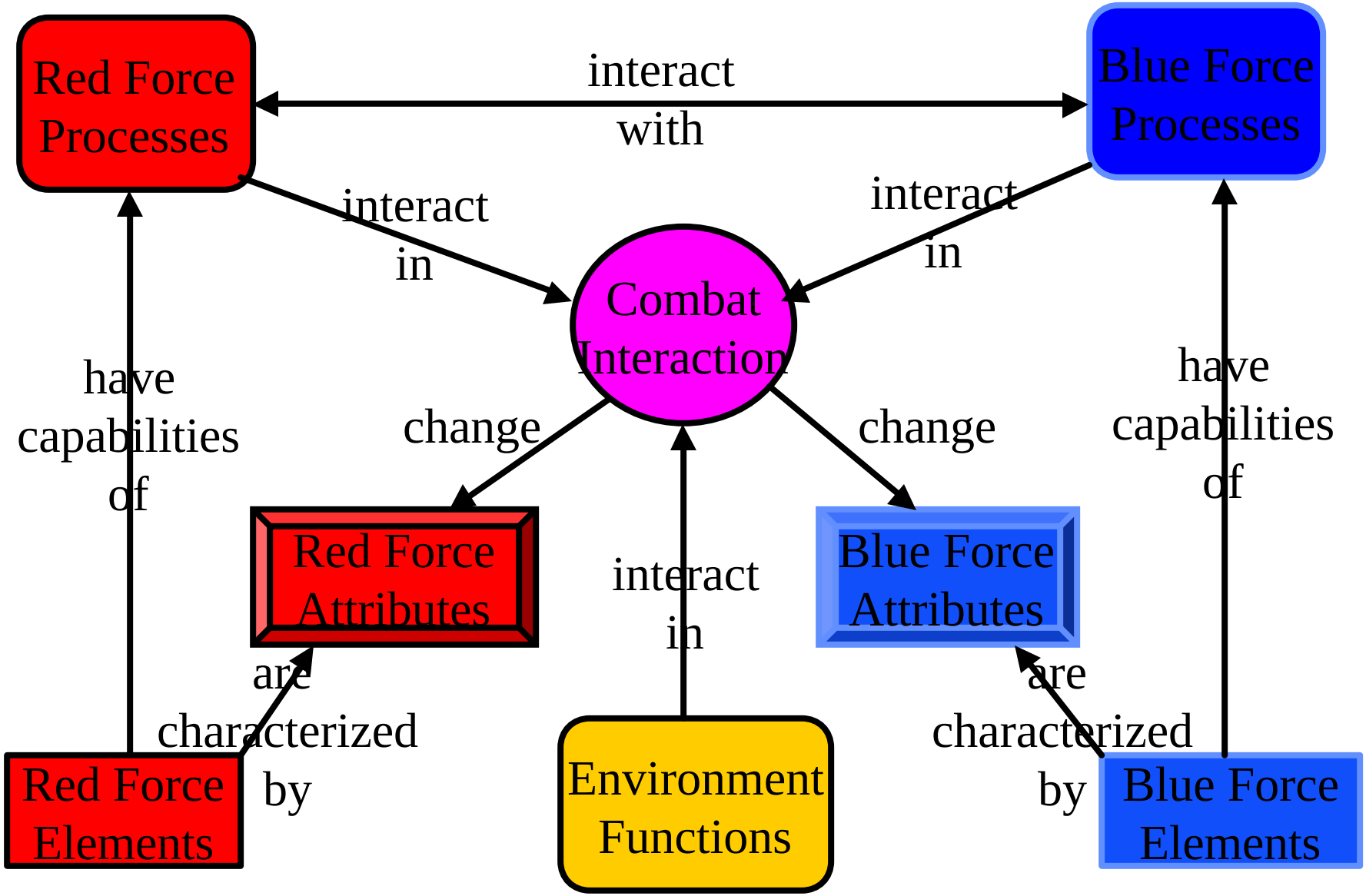
Second, a change of state in the S-M-T fault trees

The fault trees of interest are the joins between the branches connected to completed Task and the branches connected to the affected Task (there may be many branches and many joins).

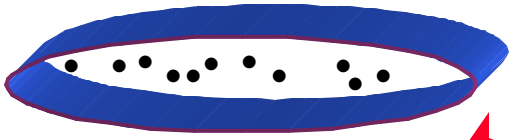
Third, a change in Conditions imposed on the Task

his influence will be implicit (in the task environment) rather than explicit as a direct input to the Task (in the task interaction itself).

Combat Descriptor Relationships



Mission Utility

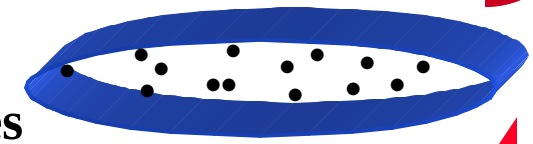


Level 4

Operational Testing

$O_{3,4}$ Operator

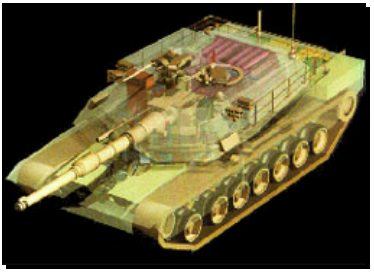
Functional Capabilities



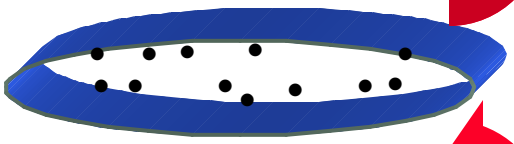
Level 3

Developmental Testing

$O_{2,3}$ Operator



Internal Conditions

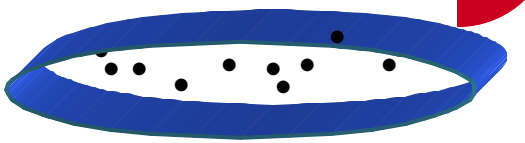


Level 2

Developmental Testing

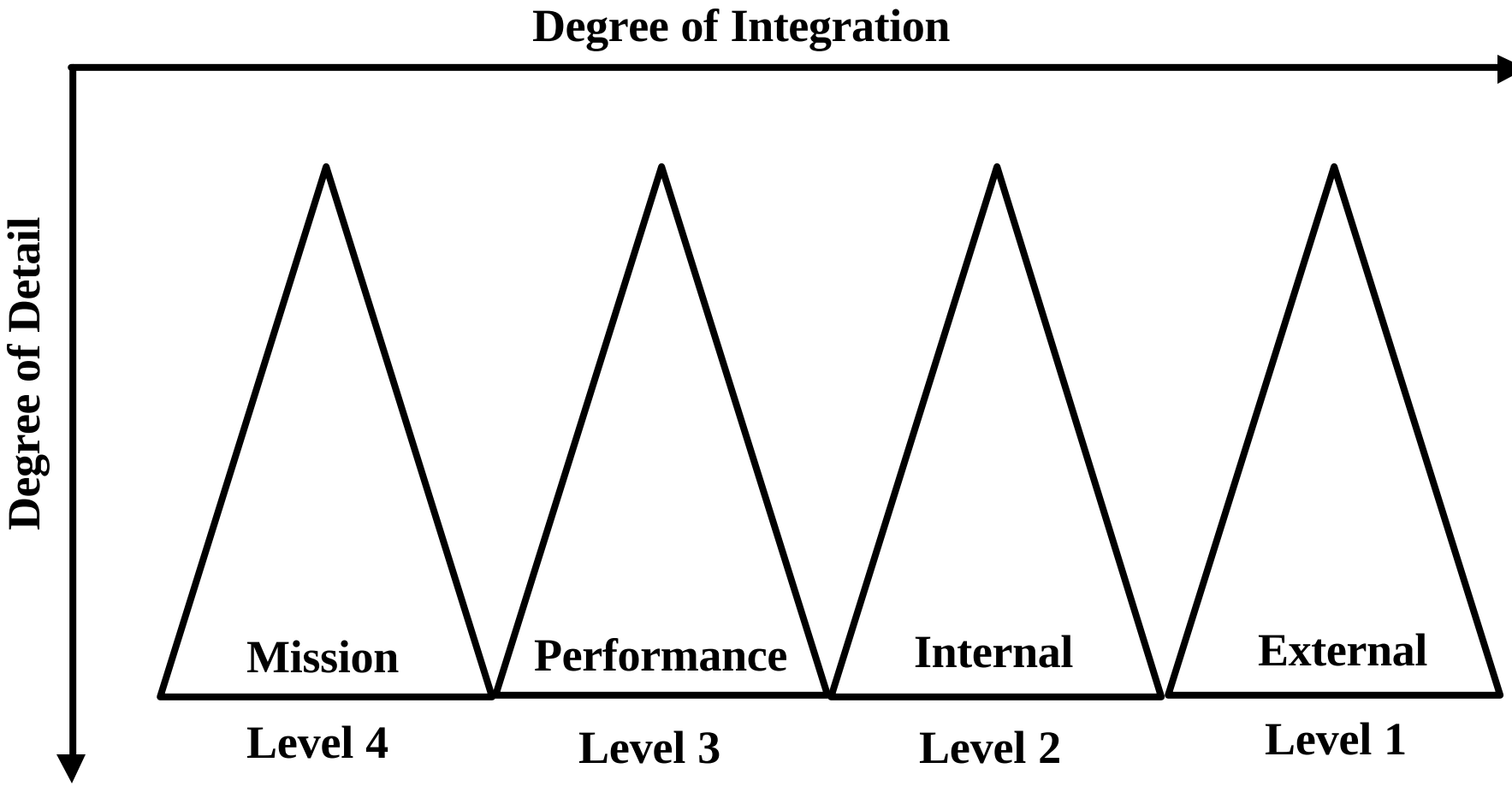
$O_{1,2}$ Operator

External Conditions



Level 1

Using MDRF


Degree of Integration
Degree of Detail
Mission
Performance
Internal
External
Level 4
Level 3
Level 2
Level 1

Key Information to Convey:

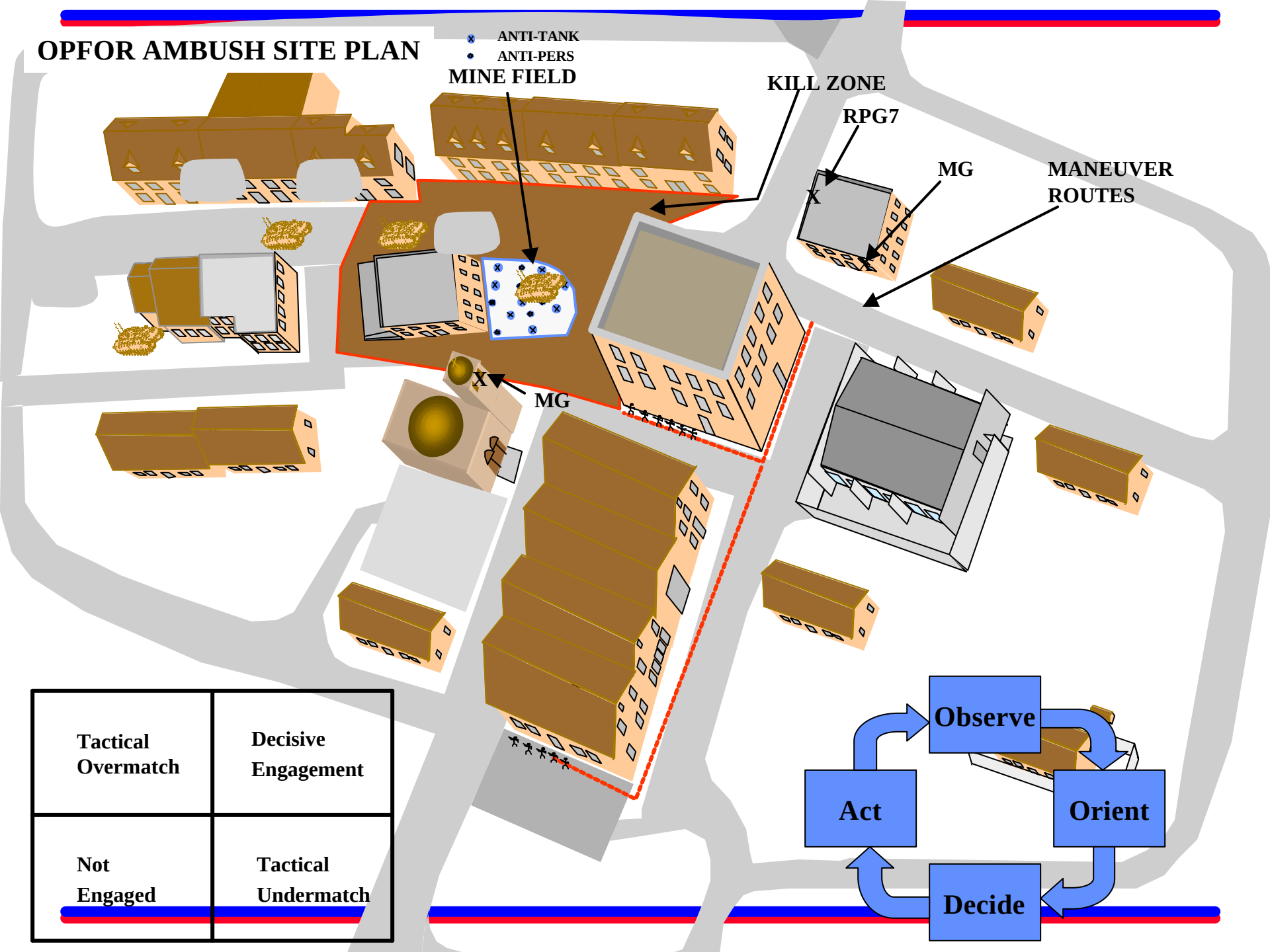
- Problem
- Objectives
- Alternatives
- Consequences
- Tradeoffs
- Uncertainty
- Risk
- Linked Decision

Bradley Fighting Vehicle

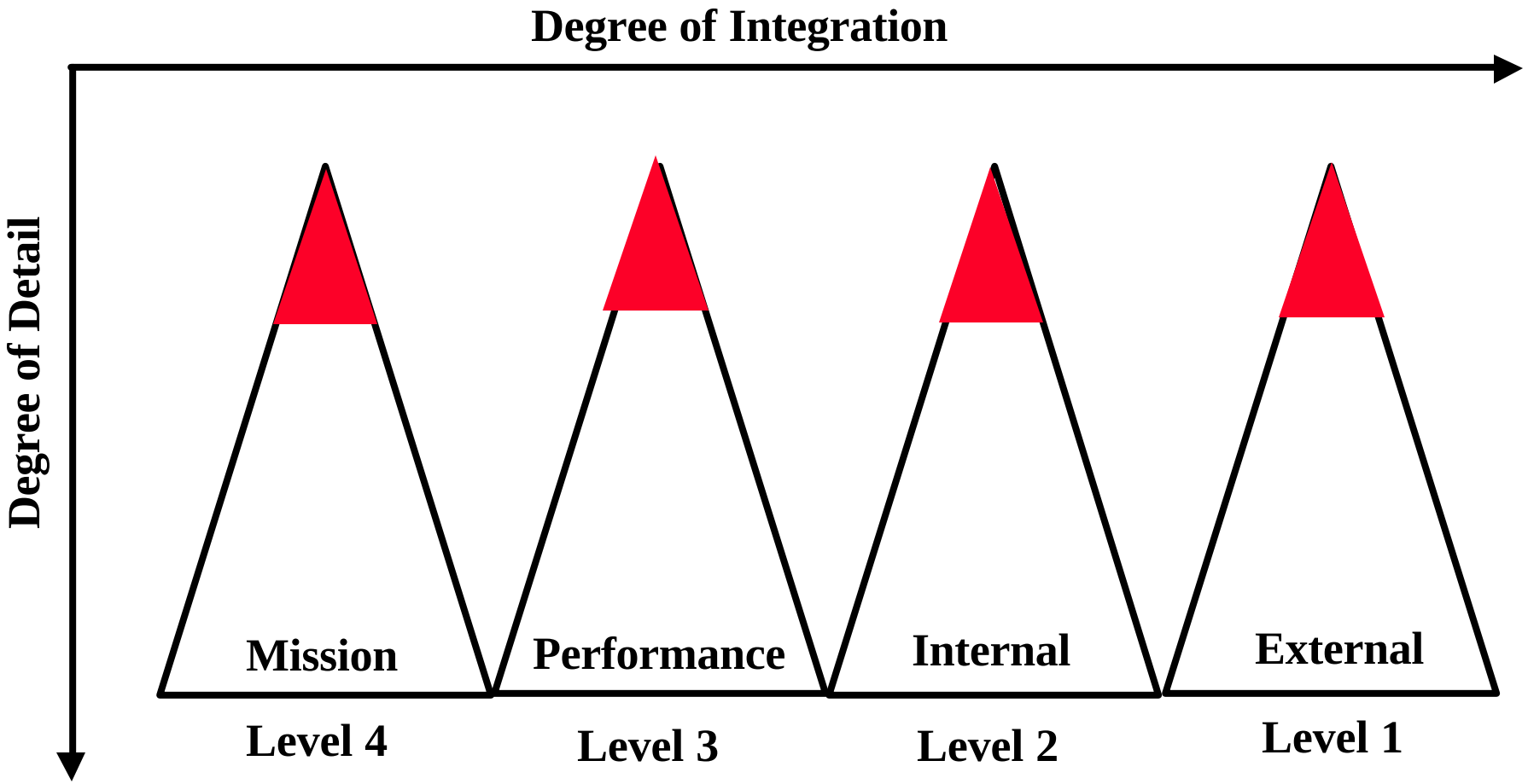
HMMWV

PANDUR

LAV III


OPFOR AMBUSH SITE PLAN
ANTI-TANK
ANTI-PERS
MINE FIELD
KILL ZONE
RPG7
MG
MANEUVER ROUTES
X
X
MG
Tactical Overmatch
Decisive Engagement
Not Engaged
Tactical Undermatch
Observe
Orient
Decide
Act

Using MDRF


Degree of Integration
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Performance
Internal
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Level 4
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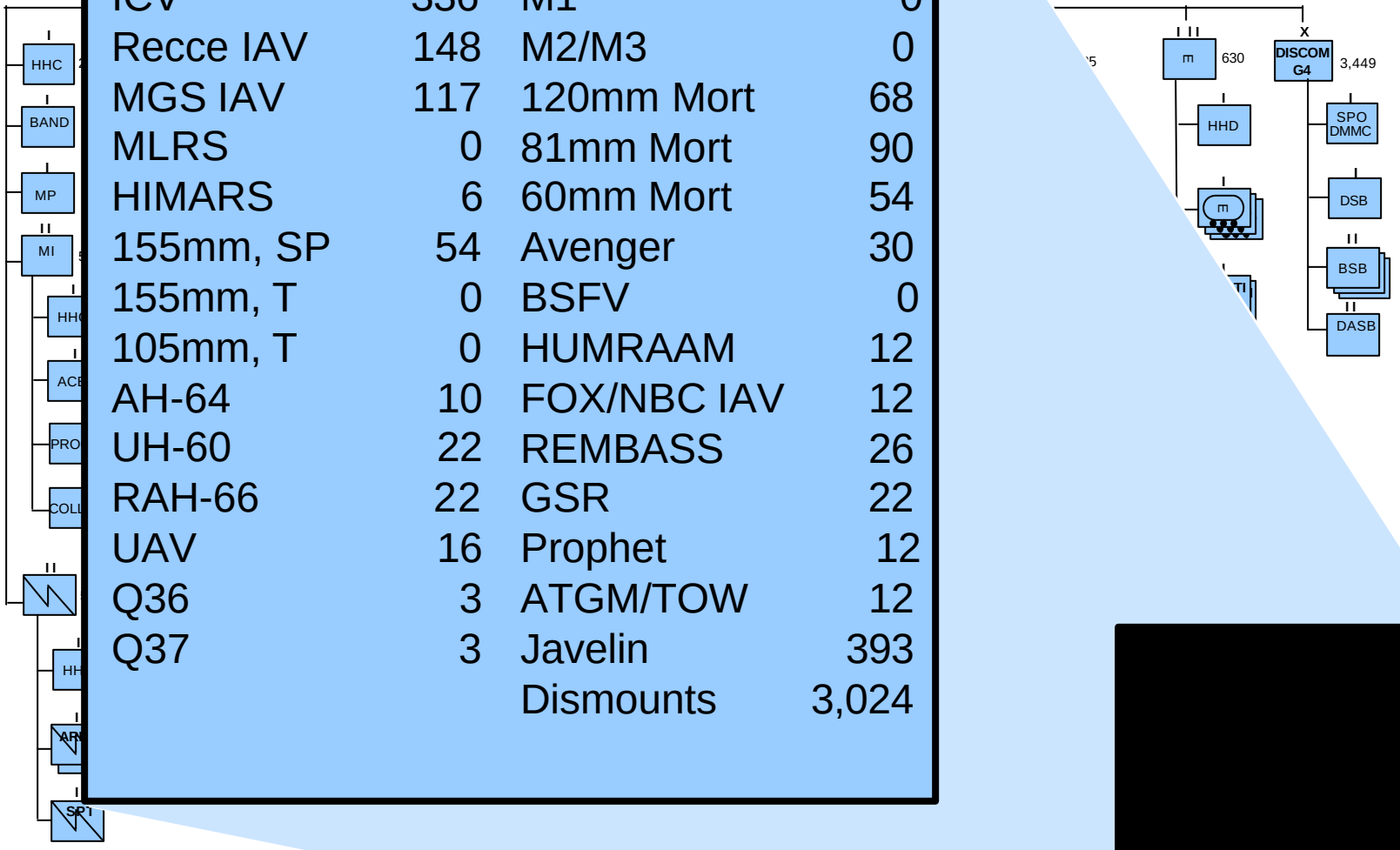
IDIV 3.0 Equipment Summary

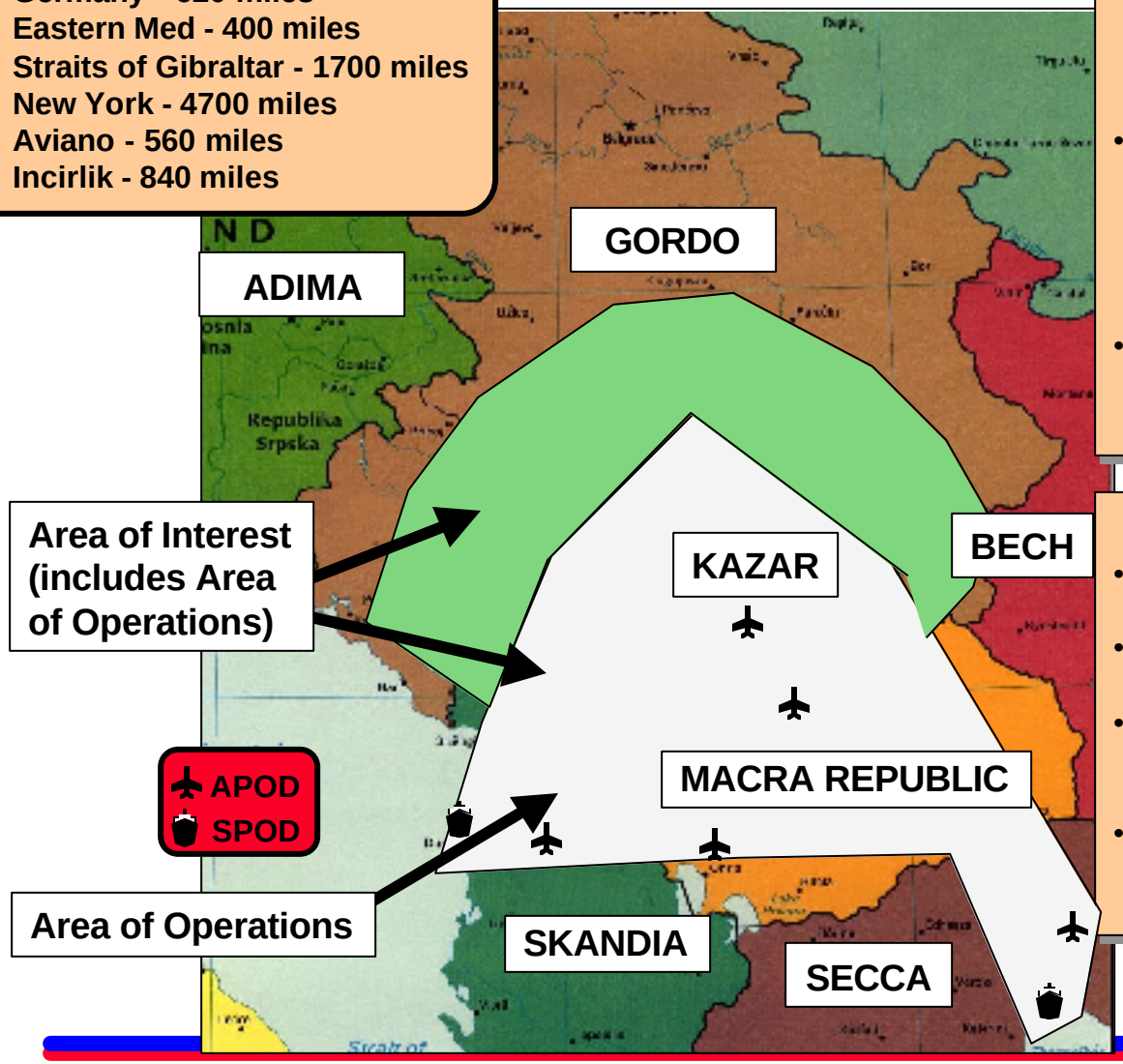
ICV	336	M1	0
Recce IAV	148	M2/M3	0
MGS IAV	117	120mm Mort	68
MLRS	0	81mm Mort	90
HIMARS	6	60mm Mort	54
155mm, SP	54	Avenger	30
155mm, T	0	BSFV	0
105mm, T	0	HUMRAAM	12
AH-64	10	FOX/NBC IAV	12
UH-60	22	REMBASS	26
RAH-66	22	GSR	22
UAV	16	Prophet	12
Q36	3	ATGM/TOW	12
Q37	3	Javelin	393
		Dismounts	3,024



Area of Operations / Area of Interest

Dist

- Germany - 620 miles
- Eastern Med - 400 miles
- Straits of Gibraltar - 1700 miles
- New York - 4700 miles
- Aviano - 560 miles
- Incirlik - 840 miles

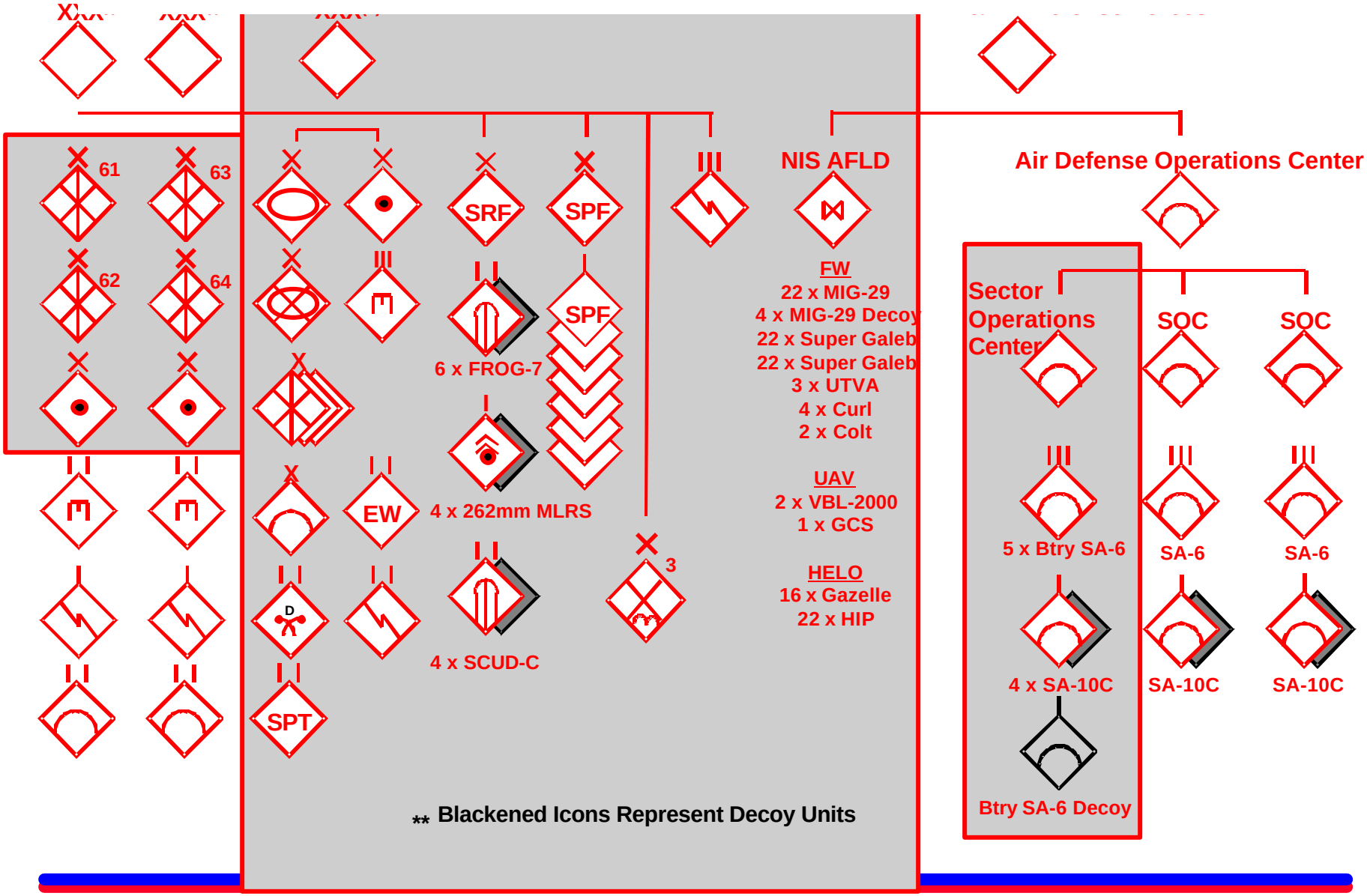


- Extremely varied; rich fertile plains in the north, limestone ranges and basins to the east, mountains and hills to the SE, extremely high shorelines to the SW
- Varying climate: cold winter and hot, humid summers with distributed rainfall in the north and central portion; along the coast, hot, dry summers and relatively cold winters with heavy snowfall inland
- Area controls one of the major land routes from Western Europe to Turkey; strategic location along the Adriatic Sea

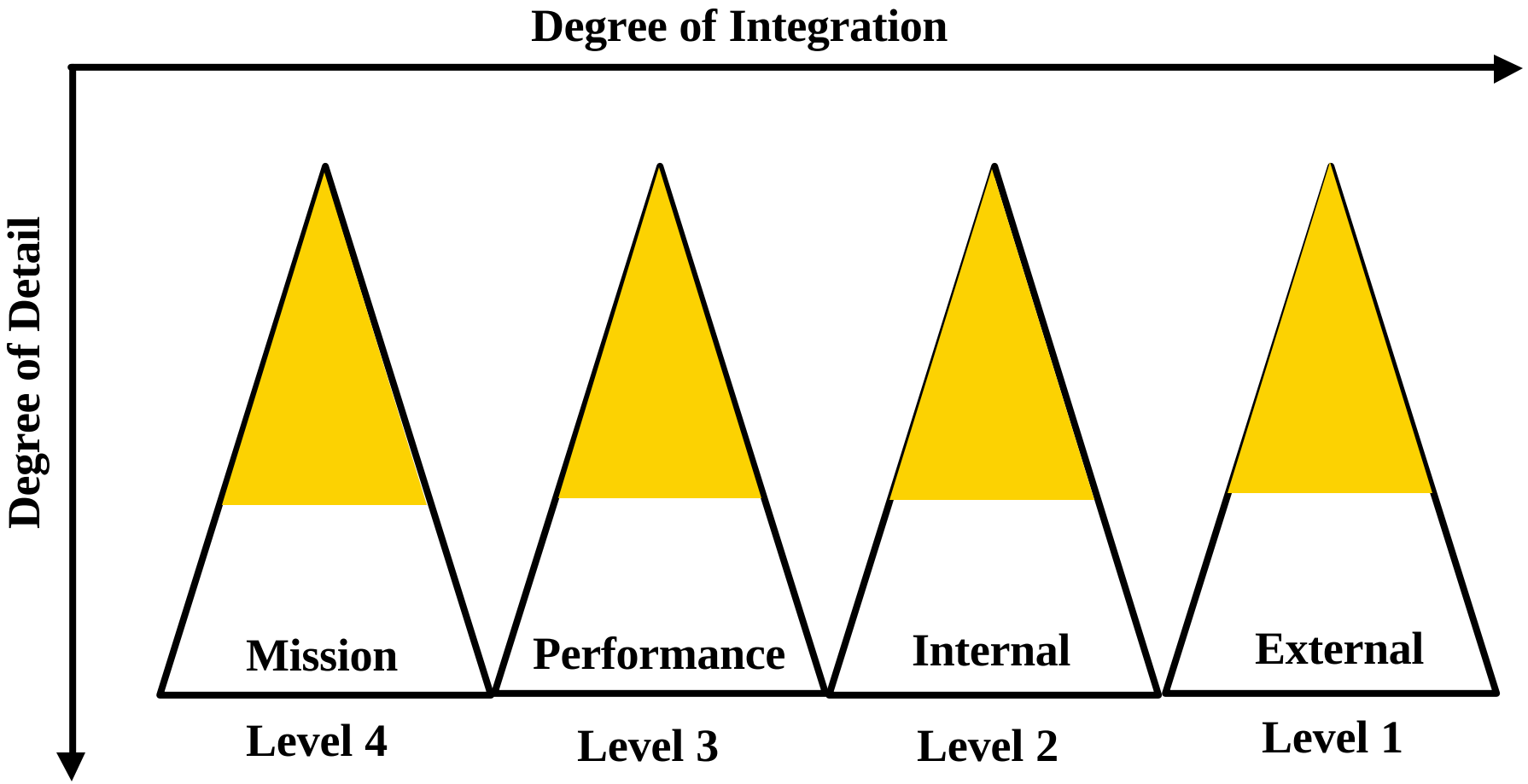
Kazar

- Republic of Gordo's southern-most province; landlocked
- Land Area: 11,000 square kilometers (slightly smaller than Connecticut)
- Bordered by Greater Gordo to north, Macra Republic to southeast, and Skandia to the southwest
- Theater of operations includes Kazar, Macra, Skandia, Secca, Gordo, Adriatic Sea, and Aviano, Italy (Air Force)

Gordian Campaign Participants



Using MDRF


Degree of Integration
Degree of Detail
Mission
Performance
Internal
External
Level 4
Level 3
Level 2
Level 1

Key Information to Convey:

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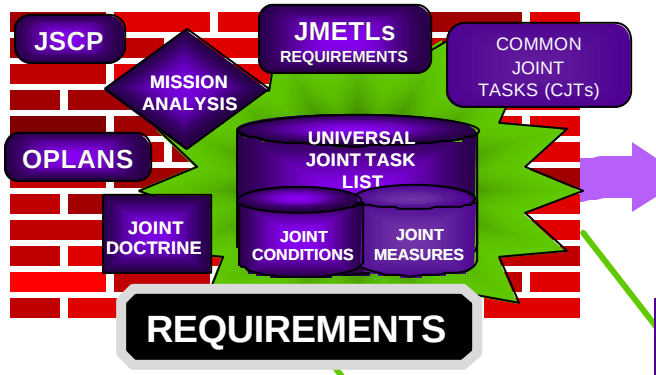
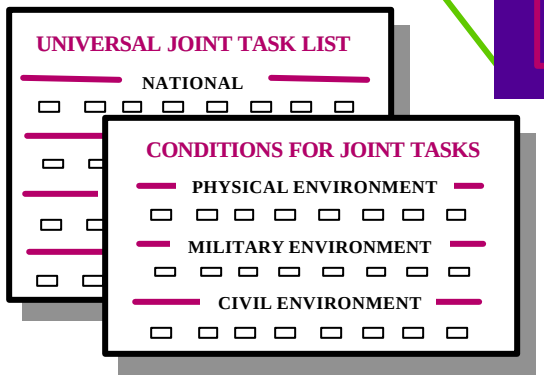
- Risk
- Linked Decision

Mission Decomposition





CJCSM 3500.04A

UNIVERSAL JOINT TASK LIST

VERSION 3.0

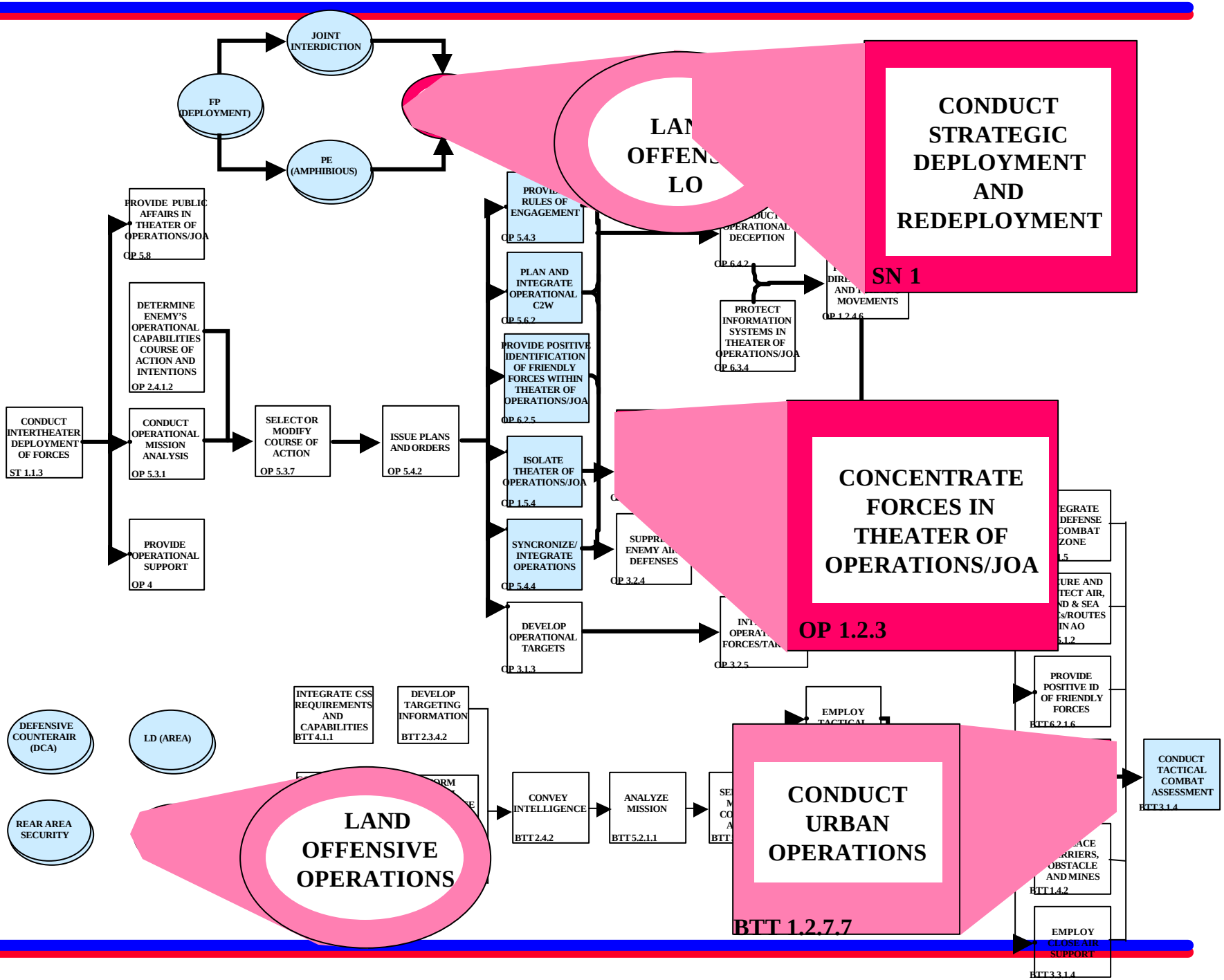
13 SEPT 1996

TASKS
- Strategic Level
  - Strategic National Tasks
  - Strategic Theater Tasks
- Operational Level Tasks
- Service Tactical Task Lists

CONDITIONS
- Physical Environment
- Military Environment
- Civil Environment

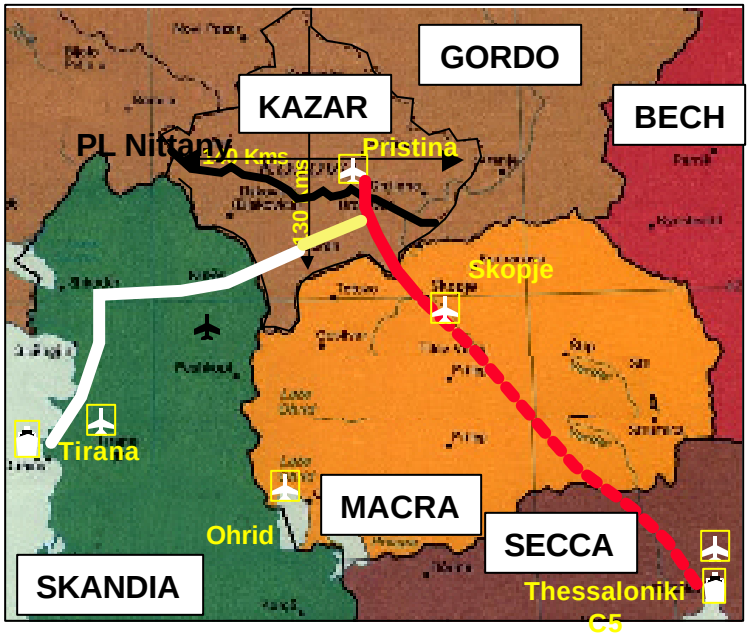
MEASURES OF PERFORMANCE
- Measure
- Scale
- Criterion - Standard

- Joint and Service UTL's
  - Provides authoritative task decomposition
  - Provides natural language descriptions with high degree of semantic consistency
  - Basis for tailored decomposition

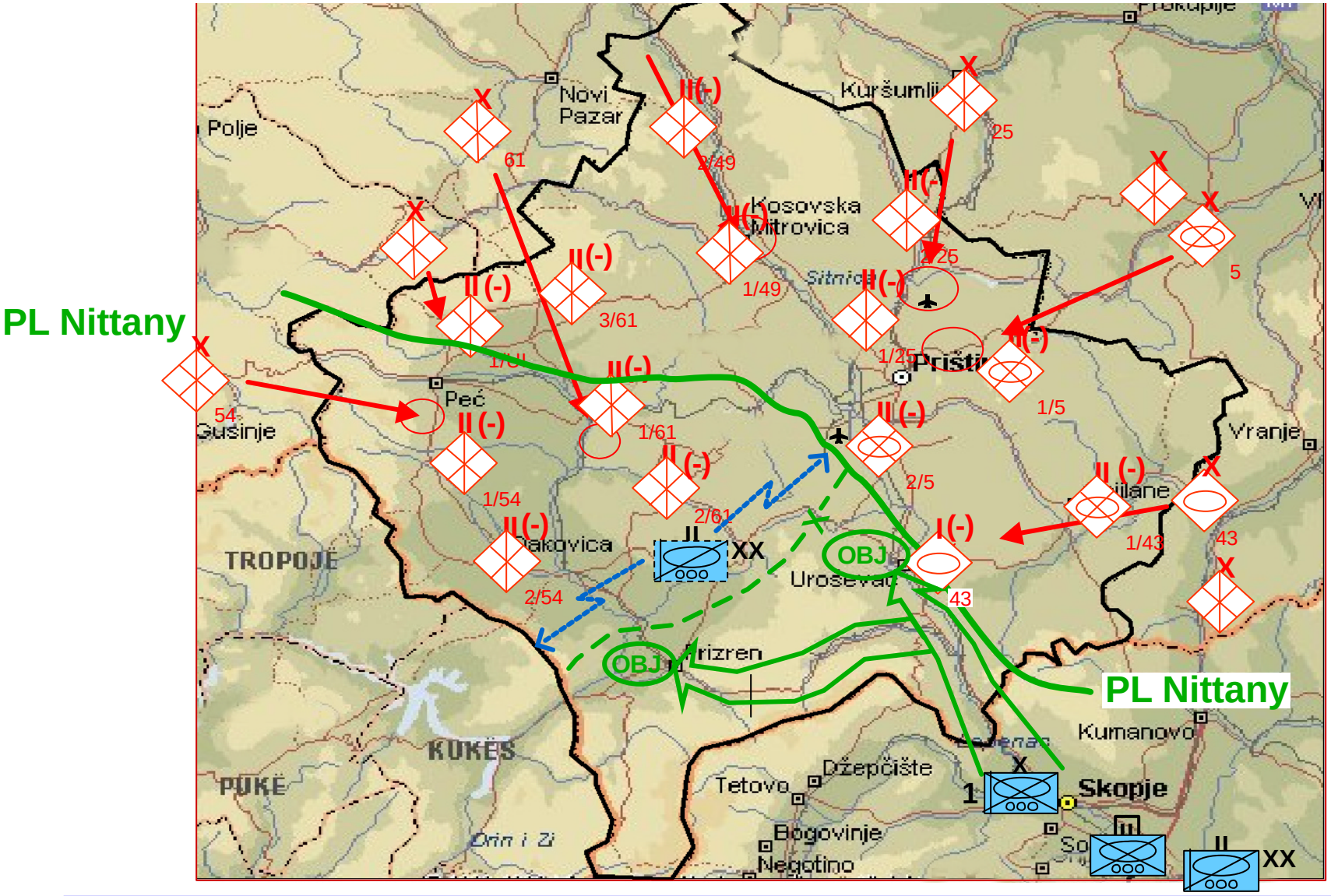

JOINT INTERDICTION
FP (DEPLOYMENT)
PE (AMPHIBIOUS)
CONDUCT STRATEGIC DEPLOYMENT AND REDEPLOYMENT
SN 1
PROVIDE PUBLIC AFFAIRS IN THEATER OF OPERATIONS/JOA
OP 5.8
DETERMINE ENEMY'S OPERATIONAL CAPABILITIES COURSE OF ACTION AND INTENTIONS
OP 2.4.1.2
CONDUCT INTERTHEATER DEPLOYMENT OF FORCES
ST 1.1.3
CONDUCT OPERATIONAL MISSION ANALYSIS
OP 5.3.1
PROVIDE OPERATIONAL SUPPORT
OP 4
SELECT OR MODIFY COURSE OF ACTION
OP 5.3.7
ISSUE PLANS AND ORDERS
OP 5.4.2
PROVIDE RULES OF ENGAGEMENT
OP 5.4.3
PLAN AND INTEGRATE OPERATIONAL C2W
OP 5.6.2
PROVIDE POSITIVE IDENTIFICATION OF FRIENDLY FORCES WITHIN THEATER OF OPERATIONS/JOA
OP 6.2.5
ISOLATE THEATER OF OPERATIONS/JOA
OP 1.5.4
SYNCRONIZE/ INTEGRATE OPERATIONS
OP 5.4.4
DEVELOP OPERATIONAL TARGETS
OP 3.1.3
PROTECT INFORMATION SYSTEMS IN THEATER OF OPERATIONS/JOA
OP 6.3.4
CONCENTRATE FORCES IN THEATER OF OPERATIONS/JOA
OP 1.2.3
DEFENSIVE COUNTERAIR (DCA)
LD (AREA)
REAR AREA SECURITY
INTEGRATE CSS REQUIREMENTS AND CAPABILITIES
BTT 4.1.1
DEVELOP TARGETING INFORMATION
BTT 2.3.4.2
CONVEY INTELLIGENCE
BTT 2.4.2
ANALYZE MISSION
BTT 5.2.1.1
LAND OFFENSIVE OPERATIONS
CONDUCT URBAN OPERATIONS
BTT 1.2.7.7
PROVIDE POSITIVE ID OF FRIENDLY FORCES
BTT 6.2.1.6
CONDUCT TACTICAL COMBAT ASSESSMENT
BTT 3.1.4
EMPLOY CLOSE AIR SUPPORT
BTT 3.3.1.4

Mobility Routes and Corridors

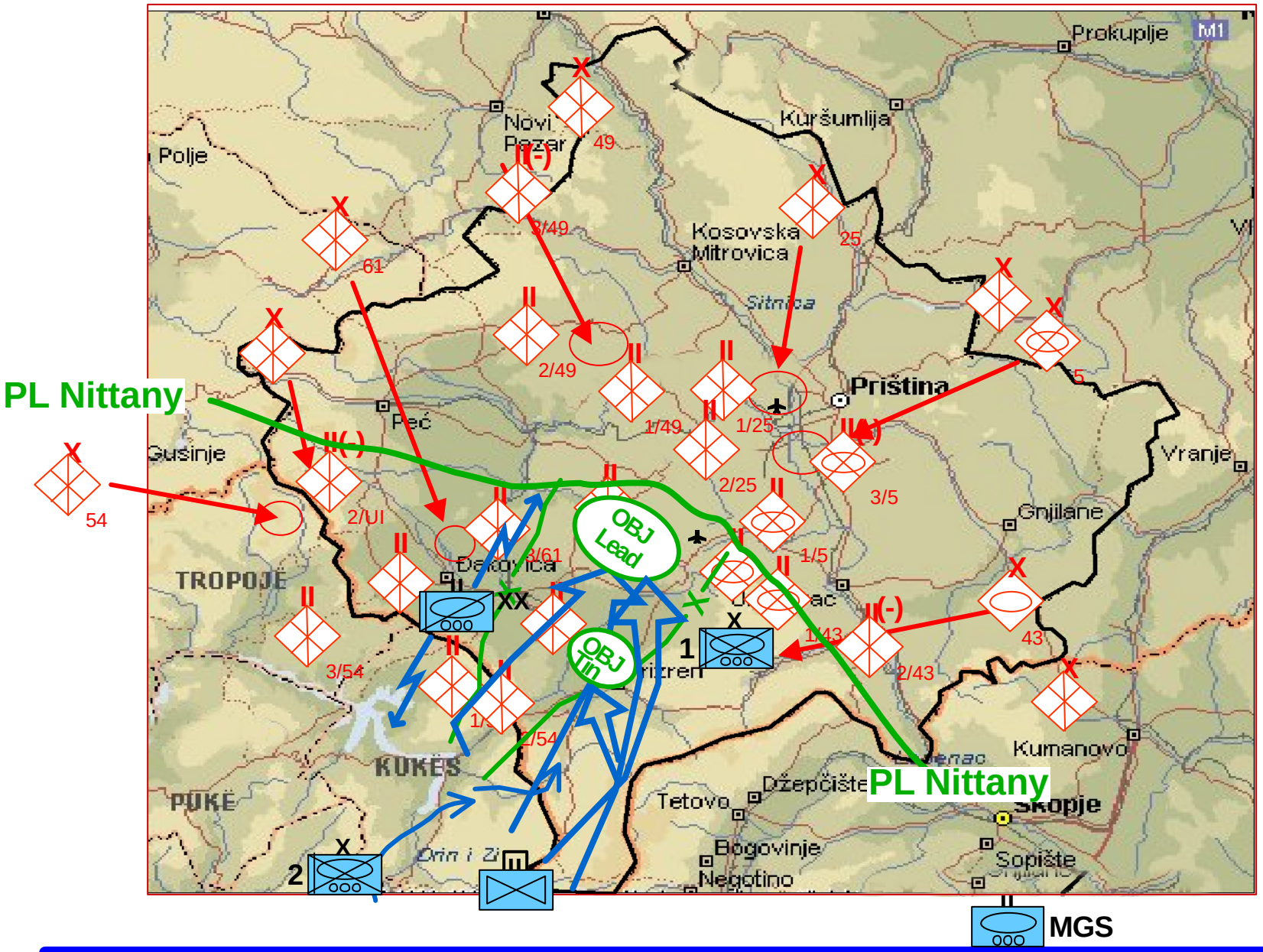
- **Durres (SPOD) - Tirana (APOD) to Prizren (includes Kukes-Prizren Corridor)**
- **Skopje (APOD) to Urosevac (includes Kacanic Pass)**
- **East-West corridor of Kazar (Urosevac-Prizren)**



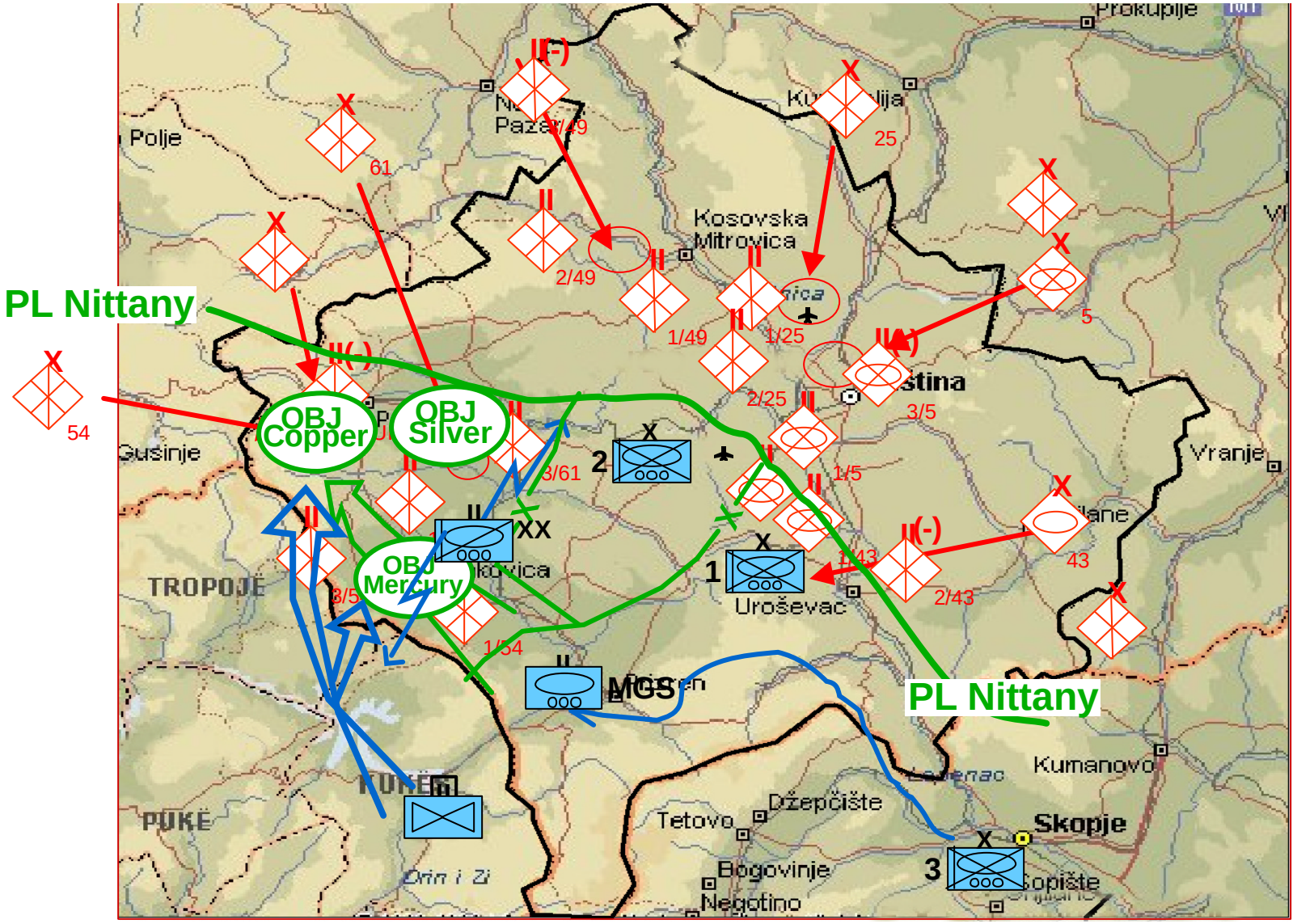
Phase 1A


PL Nittany
Novi Pazar
Polje
Kosovska Mitrovica
Kuršumlija
Peć
Gusinje
TROPOJE
Prizren
Uroševac
Vranje
Kumanovo
Tetovo
Džepčište
Skopje
Bogovinje
Negotino
KUKËS
PUKË
OBJ
PL Nittany
61
2/49
25
1/49
3/61
1/25
5
54
1/61
1/5
2/5
1/54
2/61
43
2/54
1/43
XX

Phase 1B


PL Nittany
54
61
49
3/49
2/49
1/49
1/25
25
2/25
3/5
2/UI
3/61
1/5
1/43
2/43
43
3/54
2/54
OBJ Lead
OBJ Lin
XX
1
2
PL Nittany
MGS
Prokuplje
Kuršumlija
Novi Pazar
Kosovska Mitrovica
Sitnica
Priština
Peć
Gusinje
Vranje
Gnjilane
Đakovica
TROPOJE
KUKES
PUKË
Tetovo
Džepčište
Kumanovo
Skopje
Bogovinje
Negotino
Sopište

Phase 1C


PL Nittany
OBJ Copper
OBJ Silver
OBJ Mercury
PL Nittany
MGS
Kosovska Mitrovica
Uroševac
Kumanovo
Skopje
Tetovo
Džepčište
Bogovinje
Negotino
Vranje
Gusinje
TROPOJE
PUKË
Polje
Prokuplje
54
61
2/49
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2/25
3/5
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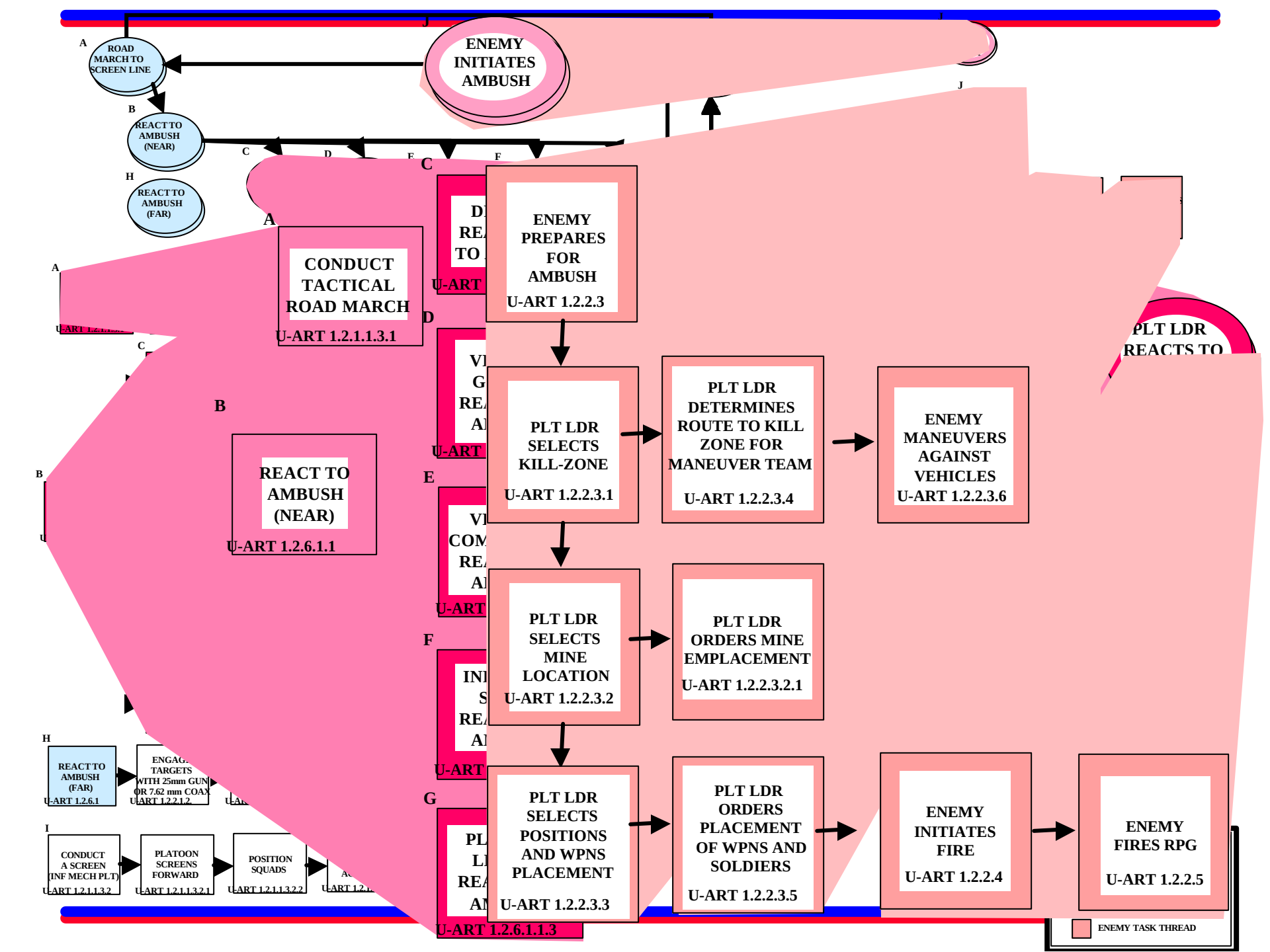
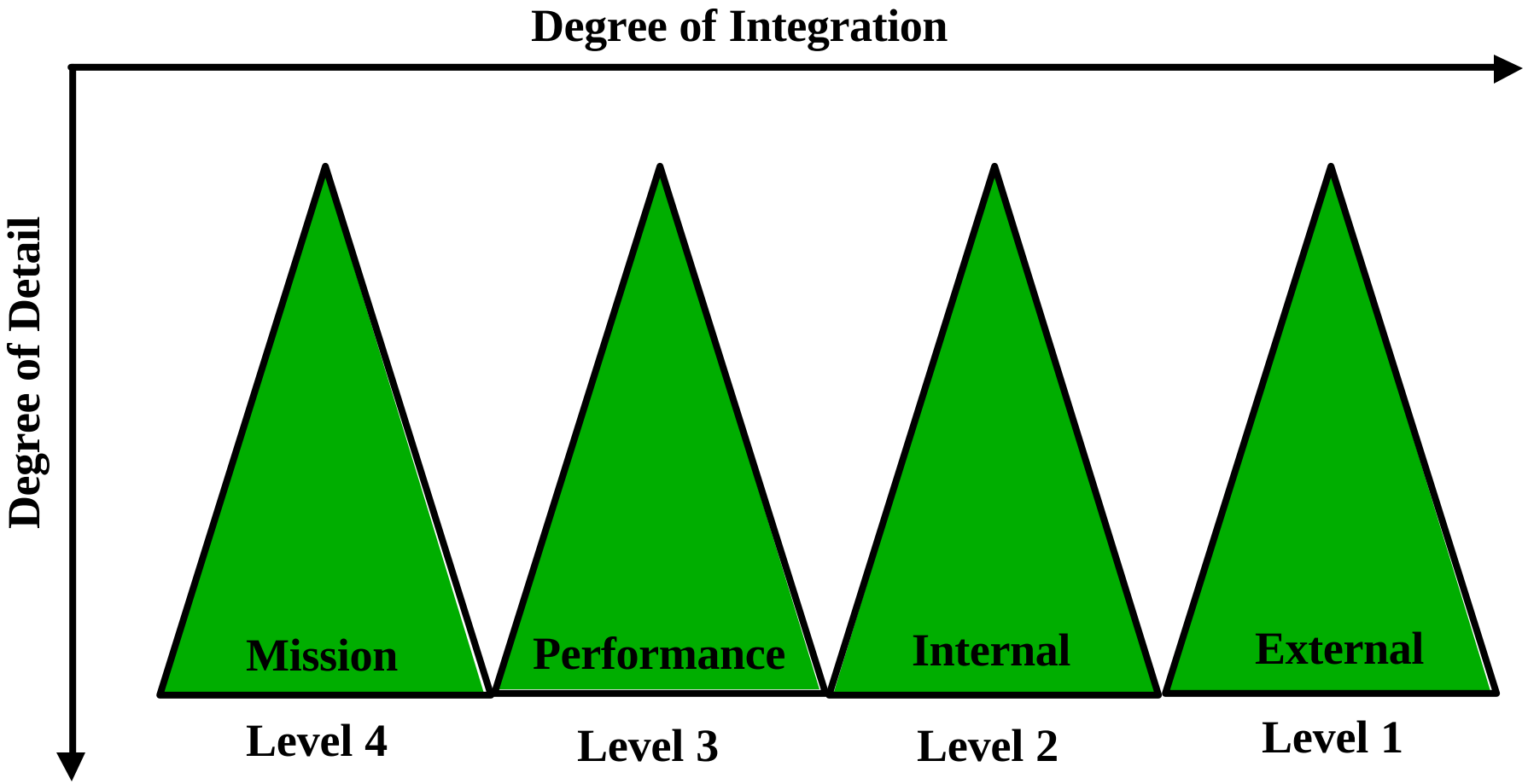
2/43
43
5
25
3/61
1/54
3/5


ROAD MARCH TO SCREEN LINE
REACT TO AMBUSH (NEAR)
REACT TO AMBUSH (FAR)
ENEMY INITIATES AMBUSH
CONDUCT TACTICAL ROAD MARCH
U-ART 1.2.1.1.3.1
REACT TO AMBUSH (NEAR)
U-ART 1.2.6.1.1
ENEMY PREPARES FOR AMBUSH
U-ART 1.2.2.3
PLT LDR SELECTS KILL-ZONE
U-ART 1.2.2.3.1
PLT LDR DETERMINES ROUTE TO KILL ZONE FOR MANEUVER TEAM
U-ART 1.2.2.3.4
ENEMY MANEUVERS AGAINST VEHICLES
U-ART 1.2.2.3.6
PLT LDR SELECTS MINE LOCATION
U-ART 1.2.2.3.2
PLT LDR ORDERS MINE EMPLACEMENT
U-ART 1.2.2.3.2.1
PLT LDR SELECTS POSITIONS AND WPNS PLACEMENT
U-ART 1.2.2.3.3
PLT LDR ORDERS PLACEMENT OF WPNS AND SOLDIERS
U-ART 1.2.2.3.5
ENEMY INITIATES FIRE
U-ART 1.2.2.4
ENEMY FIRES RPG
U-ART 1.2.2.5
REACT TO AMBUSH (FAR)
U-ART 1.2.6.1
CONDUCT A SCREEN (INF MECH PLT)
U-ART 1.2.1.1.3.2
PLATOON SCREENS FORWARD
U-ART 1.2.1.1.3.2.1
POSITION SQUADS
U-ART 1.2.1.1.3.2.2
ENEMY TASK THREAD

Using MDRF


Degree of Integration
Degree of Detail
Mission
Performance
Internal
External
Level 4
Level 3
Level 2
Level 1

Key Information to Convey:

- Problem
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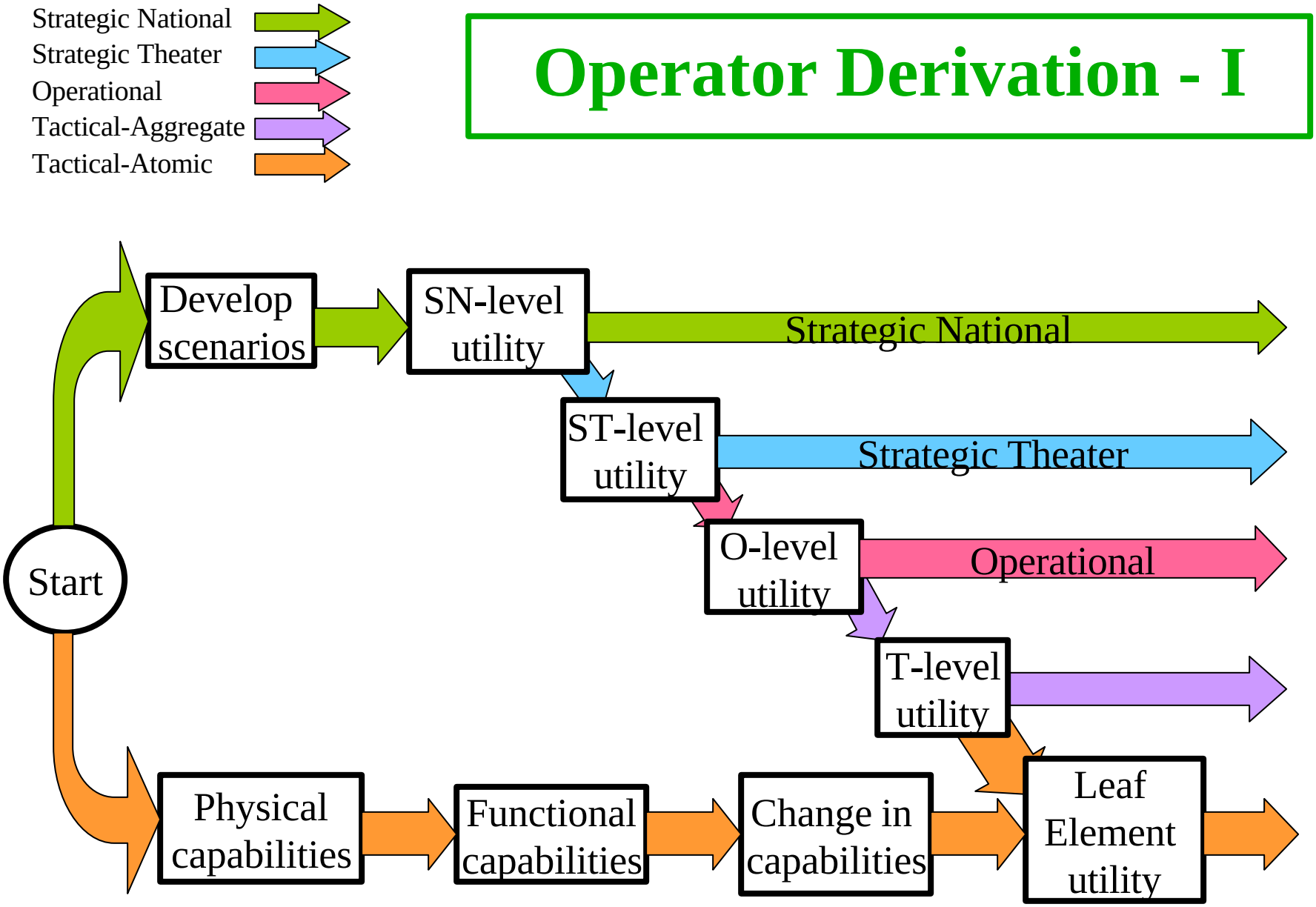
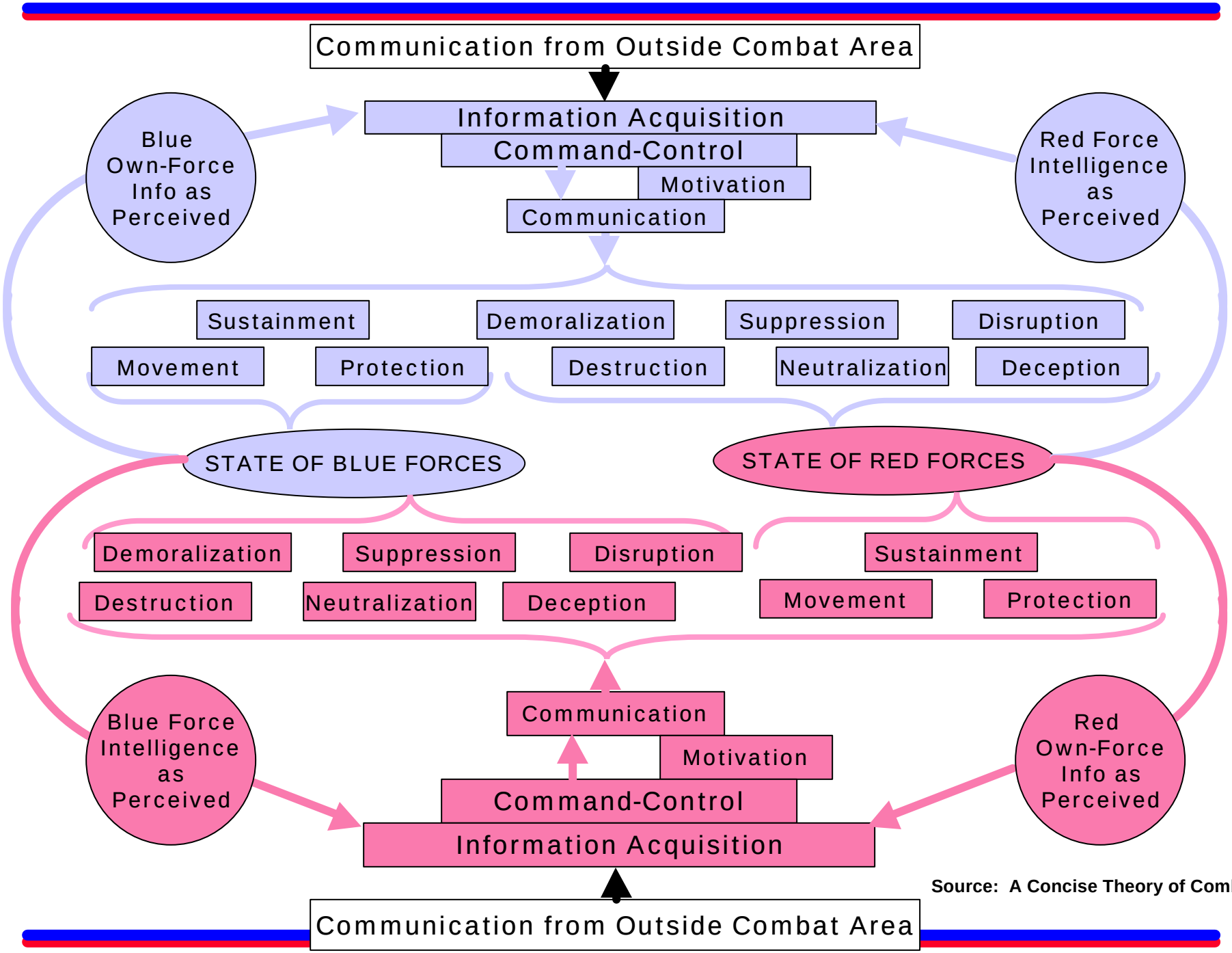
- Risk
- Linked Decision

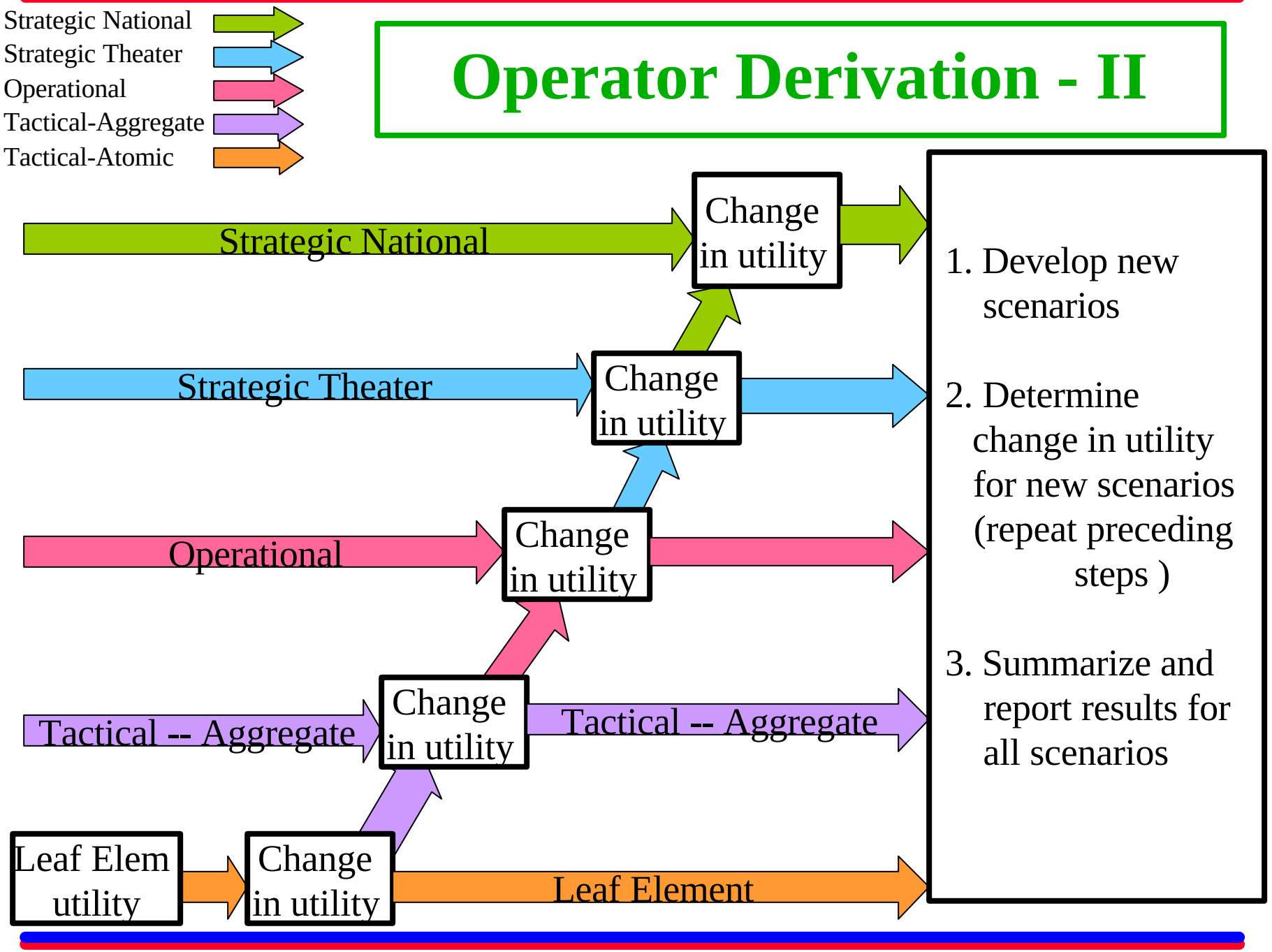
Operator Derivation - I

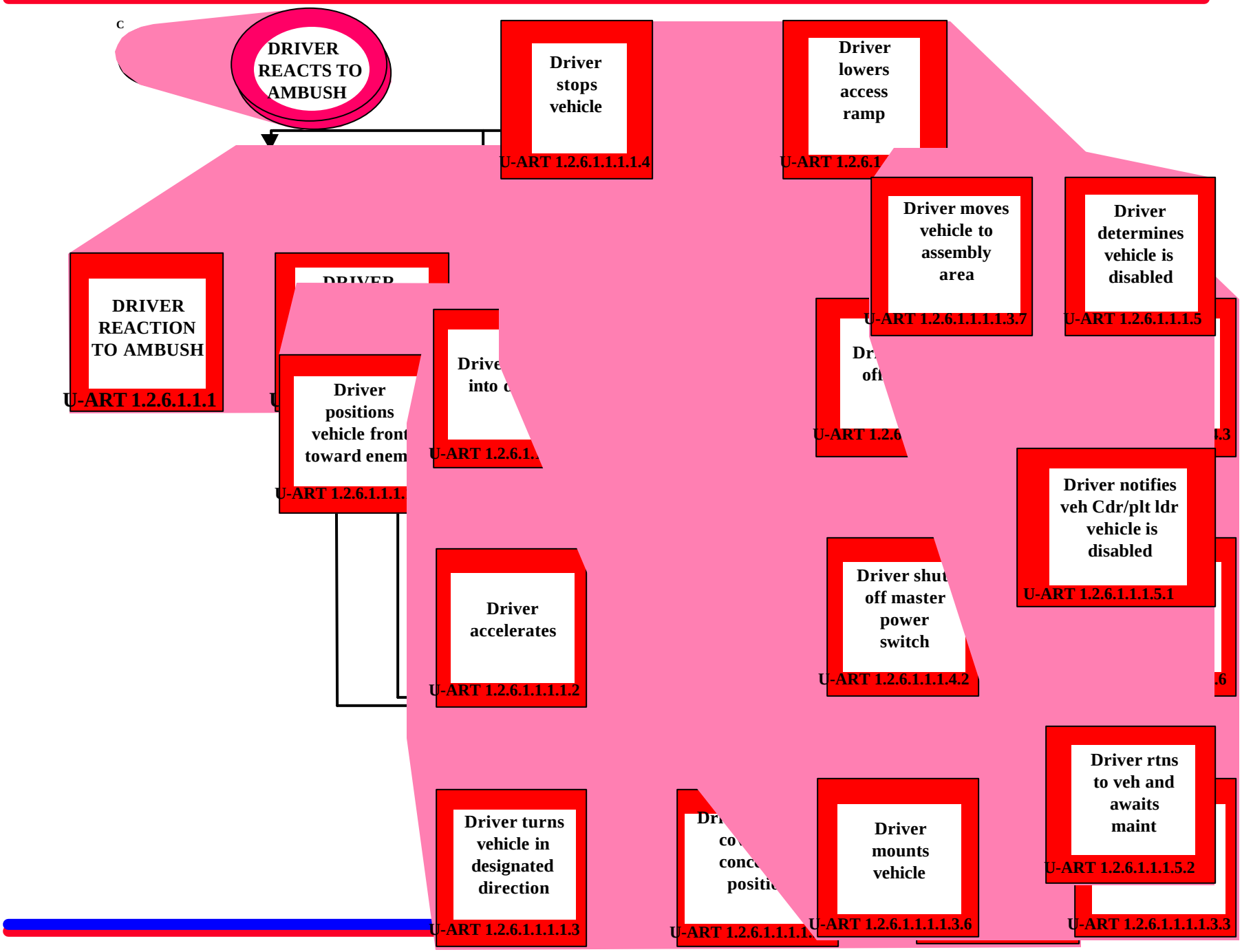


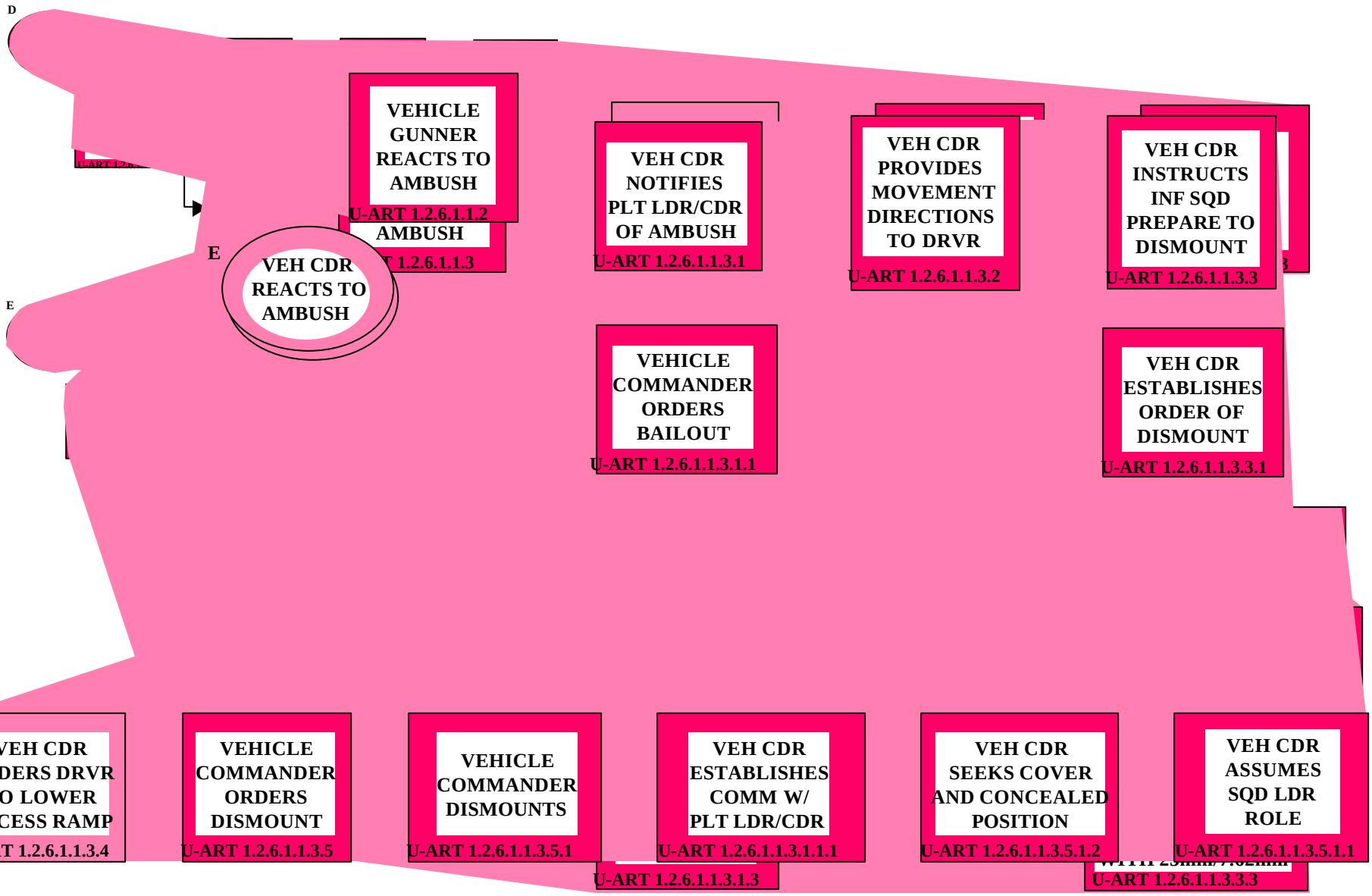


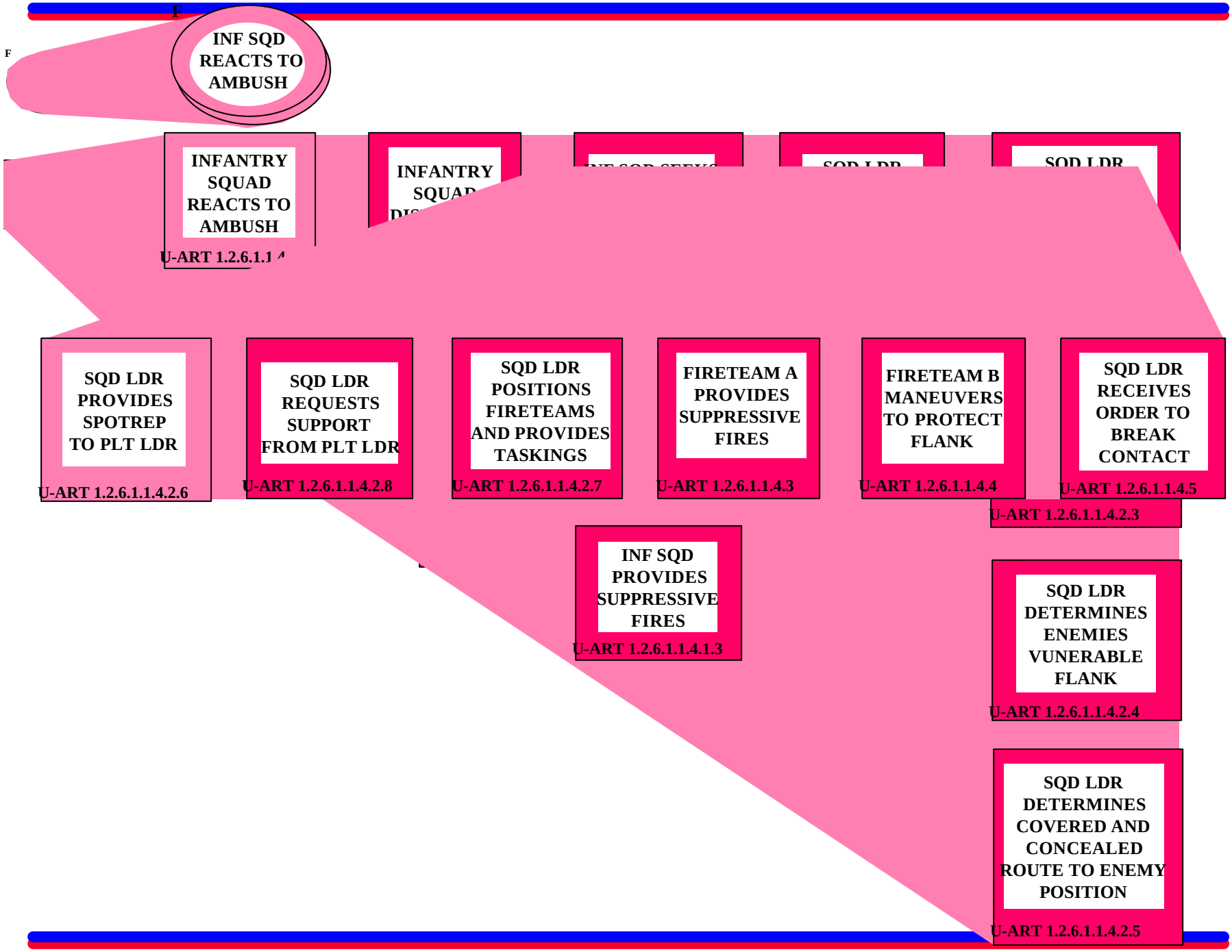
Source: A Concise Theory of Combat

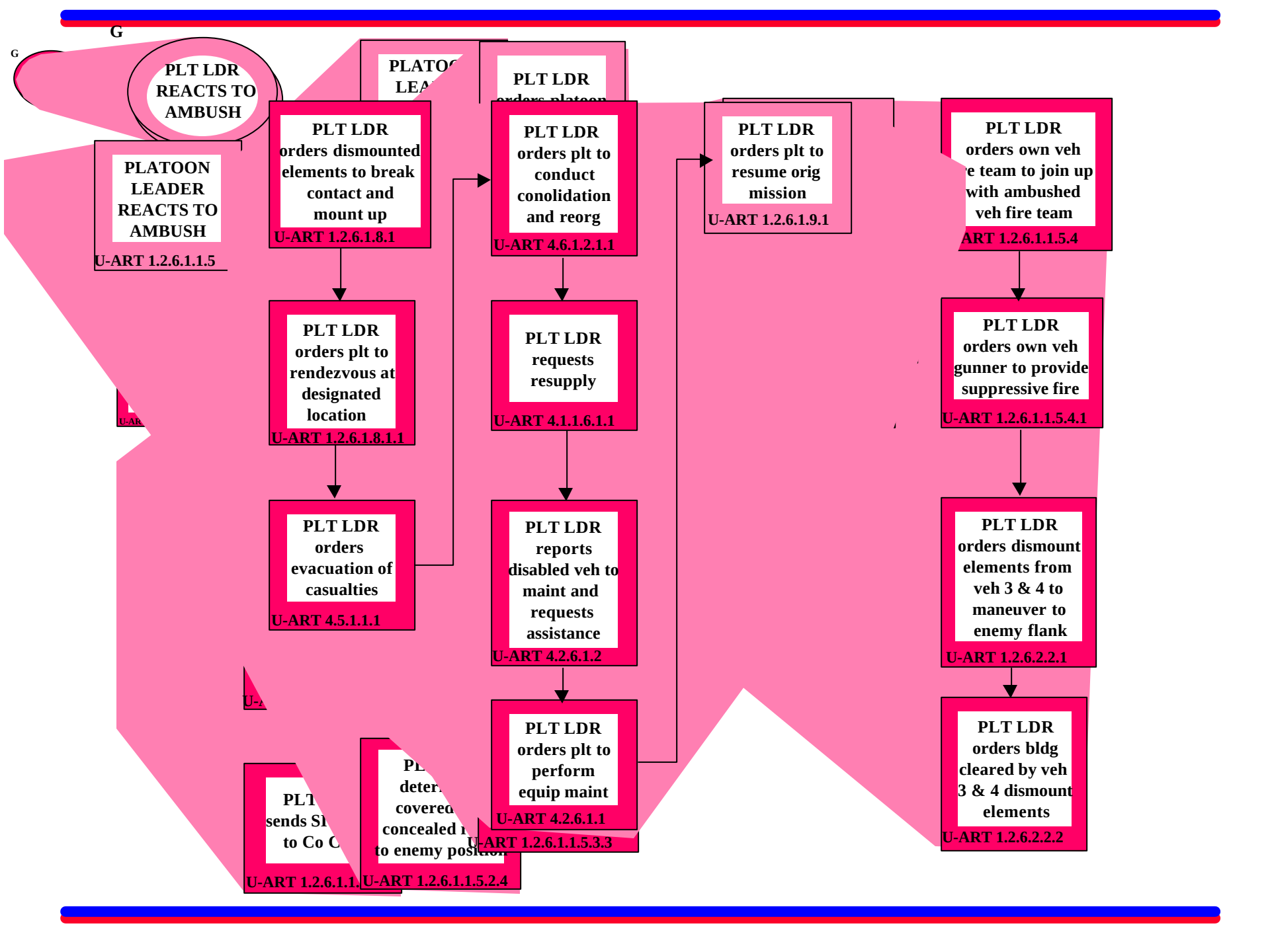
Operator Derivation - II

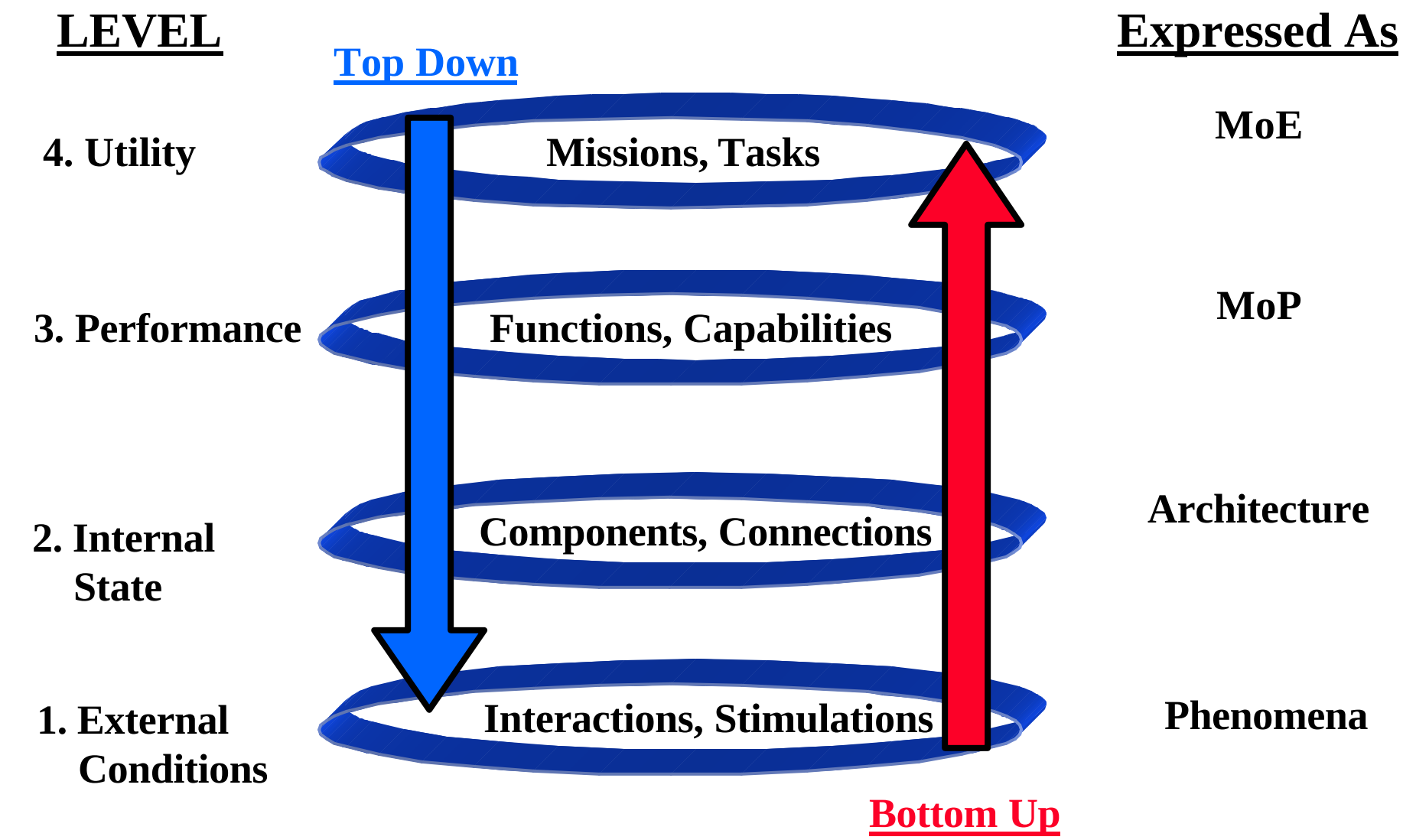


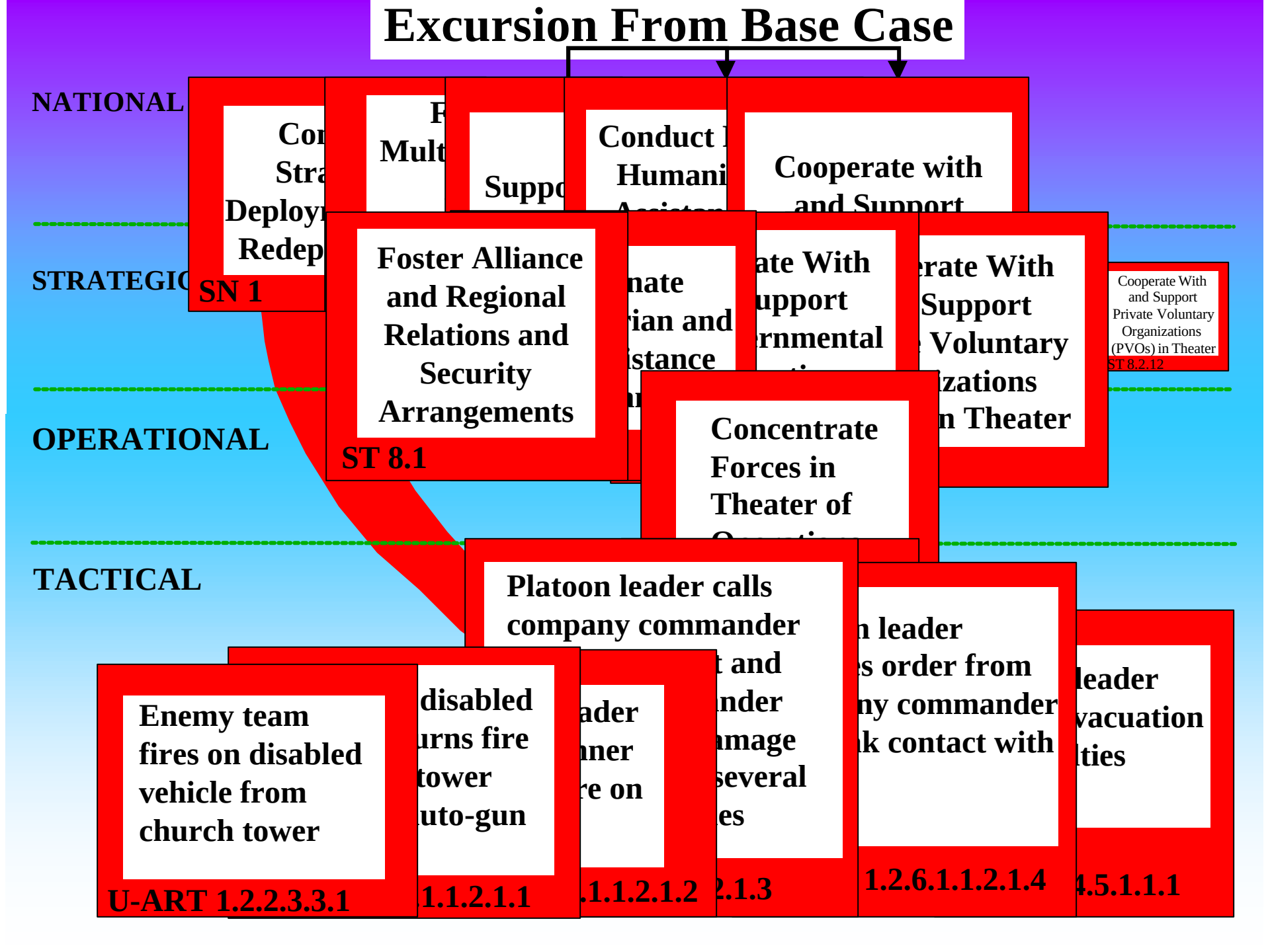

C
DRIVER REACTS TO AMBUSH
Driver stops vehicle
U-ART 1.2.6.1.1.1.1.4
Driver lowers access ramp
U-ART 1.2.6.1
Driver moves vehicle to assembly area
U-ART 1.2.6.1.1.1.3.7
Driver determines vehicle is disabled
U-ART 1.2.6.1.1.5
DRIVER REACTION TO AMBUSH
U-ART 1.2.6.1.1.1
Driver positions vehicle front
toward enem
U-ART 1.2.6.1.1.1.
Drive
into
U-ART 1.2.6.1.
Dr
off
U-ART 1.2.6
Driver notifies veh Cdr/plt ldr vehicle is disabled
U-ART 1.2.6.1.1.5.1
Driver accelerates
U-ART 1.2.6.1.1.1.1.2
Driver shut off master power switch
U-ART 1.2.6.1.1.4.2
Driver rtns to veh and awaits maint
U-ART 1.2.6.1.1.5.2
Driver turns vehicle in designated direction
U-ART 1.2.6.1.1.1.3
Dr
co
conc
positi
U-ART 1.2.6.1.1.1.
Driver mounts vehicle
U-ART 1.2.6.1.1.1.3.6
U-ART 1.2.6.1.1.1.3.3


D
E
E
VEHICLE GUNNER REACTS TO AMBUSH
U-ART 1.2.6.1.1.2
AMBUSH
T 1.2.6.1.1.3
VEH CDR REACTS TO AMBUSH
VEH CDR NOTIFIES PLT LDR/CDR OF AMBUSH
U-ART 1.2.6.1.1.3.1
VEH CDR PROVIDES MOVEMENT DIRECTIONS TO DRVR
U-ART 1.2.6.1.1.3.2
VEH CDR INSTRUCTS INF SQD PREPARE TO DISMOUNT
U-ART 1.2.6.1.1.3.3
VEHICLE COMMANDER ORDERS BAILOUT
U-ART 1.2.6.1.1.3.1.1
VEH CDR ESTABLISHES ORDER OF DISMOUNT
U-ART 1.2.6.1.1.3.3.1
VEH CDR ORDERS DRVR TO LOWER ACCESS RAMP
U-ART 1.2.6.1.1.3.4
VEHICLE COMMANDER ORDERS DISMOUNT
U-ART 1.2.6.1.1.3.5
VEHICLE COMMANDER DISMOUNTS
U-ART 1.2.6.1.1.3.5.1
VEH CDR ESTABLISHES COMM W/ PLT LDR/CDR
U-ART 1.2.6.1.1.3.1.1.1
U-ART 1.2.6.1.1.3.1.3
VEH CDR SEEKS COVER AND CONCEALED POSITION
U-ART 1.2.6.1.1.3.5.1.2
VEH CDR ASSUMES SQD LDR ROLE
U-ART 1.2.6.1.1.3.5.1.1
U-ART 1.2.6.1.1.3.3.3


INF SQD REACTS TO AMBUSH
INFANTRY SQUAD REACTS TO AMBUSH
U-ART 1.2.6.1.1.4
INFANTRY SQUAD
SQD LDR
SQD LDR PROVIDES SPOTREP TO PLT LDR
U-ART 1.2.6.1.1.4.2.6
SQD LDR REQUESTS SUPPORT FROM PLT LDR
U-ART 1.2.6.1.1.4.2.8
SQD LDR POSITIONS FIRETEAMS AND PROVIDES TASKINGS
U-ART 1.2.6.1.1.4.2.7
FIRETEAM A PROVIDES SUPPRESSIVE FIRES
U-ART 1.2.6.1.1.4.3
FIRETEAM B MANEUVERS TO PROTECT FLANK
U-ART 1.2.6.1.1.4.4
SQD LDR RECEIVES ORDER TO BREAK CONTACT
U-ART 1.2.6.1.1.4.5
U-ART 1.2.6.1.1.4.2.3
INF SQD PROVIDES SUPPRESSIVE FIRES
U-ART 1.2.6.1.1.4.1.3
SQD LDR DETERMINES ENEMIES VUNERABLE FLANK
U-ART 1.2.6.1.1.4.2.4
SQD LDR DETERMINES COVERED AND CONCEALED ROUTE TO ENEMY POSITION
U-ART 1.2.6.1.1.4.2.5


G
PLT LDR REACTS TO AMBUSH
PLATOON LEADER REACTS TO AMBUSH
U-ART 1.2.6.1.1.5
PLT LDR orders dismounted elements to break contact and mount up
U-ART 1.2.6.1.8.1
PLT LDR orders plt to rendezvous at designated location
U-ART 1.2.6.1.8.1.1
PLT LDR orders evacuation of casualties
U-ART 4.5.1.1.1
PLT LDR orders plt to conduct conolidation and reorg
U-ART 4.6.1.2.1.1
PLT LDR requests resupply
U-ART 4.1.1.6.1.1
PLT LDR reports disabled veh to maint and requests assistance
U-ART 4.2.6.1.2
PLT LDR orders plt to perform equip maint
U-ART 4.2.6.1.1
U-ART 1.2.6.1.1.5.3.3
PLT LDR orders plt to resume orig mission
U-ART 1.2.6.1.9.1
PLT LDR orders own veh team to join up with ambushed veh fire team
U-ART 1.2.6.1.1.5.4
PLT LDR orders own veh gunner to provide suppressive fire
U-ART 1.2.6.1.1.5.4.1
PLT LDR orders dismount elements from veh 3 & 4 to maneuver to enemy flank
U-ART 1.2.6.2.2.1
PLT LDR orders bldg cleared by veh 3 & 4 dismount elements
U-ART 1.2.6.2.2.2
U-ART 1.2.6.1.1.5.2.4


LEVEL
Expressed As
Top Down
4. Utility
Missions, Tasks
MoE
3. Performance
Functions, Capabilities
MoP
2. Internal State
Components, Connections
Architecture
1. External Conditions
Interactions, Stimulations
Phenomena
Bottom Up


Excursion From Base Case
NATIONAL
STRATEGIC
OPERATIONAL
TACTICAL
SN 1
Foster Alliance and Regional Relations and Security Arrangements
ST 8.1
Cooperate With and Support Private Voluntary Organizations (PVOs) in Theater
ST 8.2.12
Concentrate Forces in Theater of
Platoon leader calls company commander
Enemy team fires on disabled vehicle from church tower
U-ART 1.2.2.3.3.1
1.2.6.1.1.2.1.4
4.5.1.1.1

Methodology (Part 1 of 3)
Generate a Level 4] Scenario

1) Create road-to-war to provide mission context.

2) Select an organizing principle for Combat Interactions.

3) Use hierarchical Strategy-to-Mission-to-Task (S-M-T) decomposition to organize the Combat Processes.

4) Use hierarchical Order-of-Battle decomposition to complete assignment of Task-Organized forces to Combat Processes.

5) Establish Task-based fault tree for Mission success using Measures, Conditions, and Standards for desired End-States.

6) Construct integrated Use-Case-Threads to sequence execution of Combat Processes leading to Combat Interactions.

Methodology (Part 3 of 3)
Express Warfighting Utility

9) Warfighting utility is then expressed in terms of how the noted outcomes either enable or constrain Task execution within a Mission context.

* Resounding victory in many (but not enough) branches may not lead to overall Mission success; conversely, resounding defeat in many (but not critical) branches may still lead to overall Mission success.

* Task execution becomes as much a measurable outcome as MOP and MOE of entities and can be traced for cause and effect.

* We are exploring the mathematical relationships between entity and task with the idea that they may be described by a transform yet to be derived.

Methodology (Part 2 of 3)
Compute Level 4] Effectiveness from Level 3] Performance

7) Compute Measures (of performance), under prescribed Conditions, and compare to Task-based fault tree Standards to determine the Mission outcome of a Combat Process following a Combat Interaction.

8) Determine affects on other Combat Processes. Affects can be one of three kinds:

First, a direct input to a subsequent task

Second, a change of state in the S-M-T fault trees

The fault trees of interest are the joins between the branches connected to completed Task and the branches connected to the affected Task (there may be many branches and many joins).

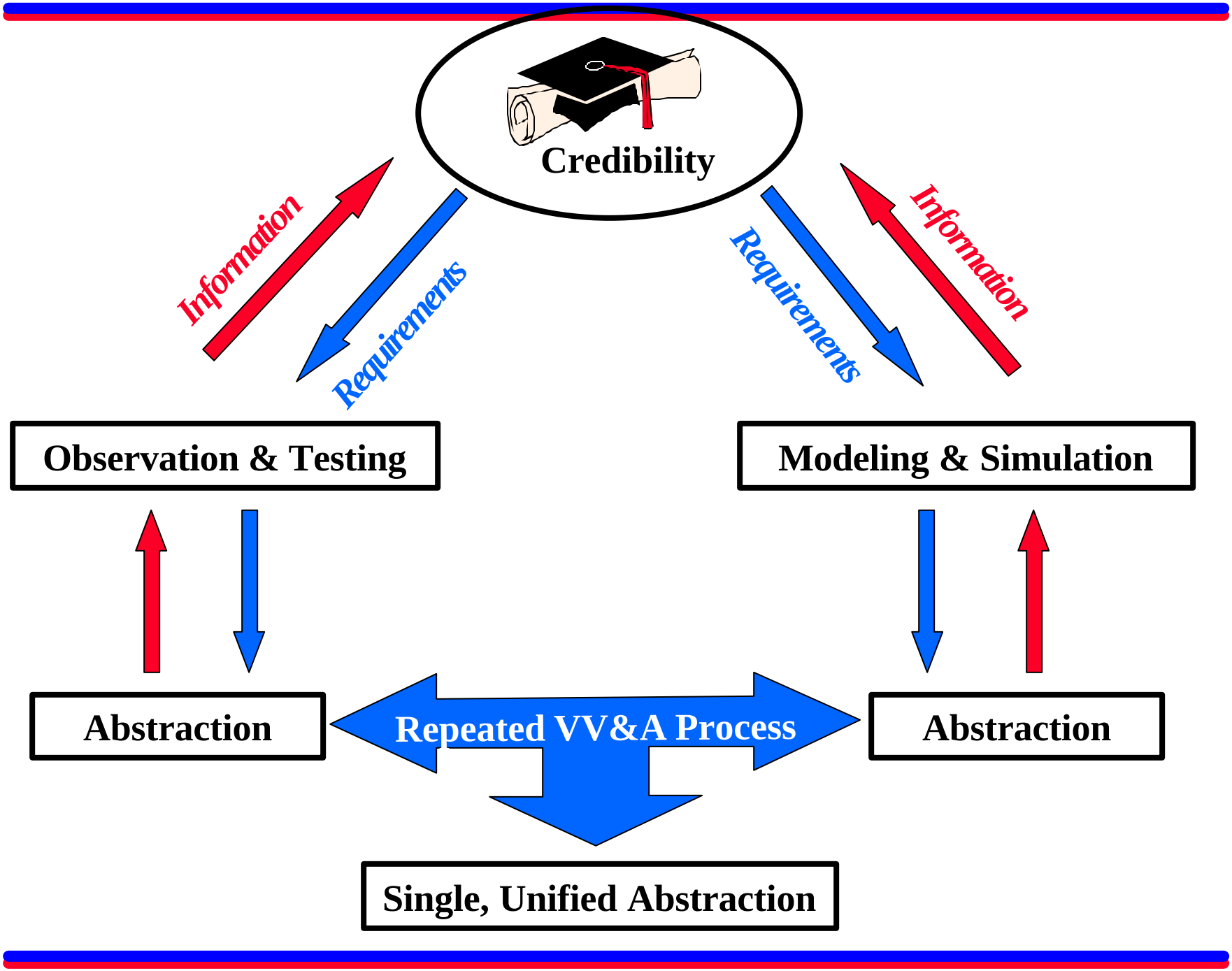
Third, a change in Conditions imposed on the Task

his influence will be implicit (in the task environment) rather than explicit as a direct input to the Task (in the task interaction itself).

Focus on the Decisions to be Informed, and the differing Perspectives of the Stakeholders

- The Warfighter cares about Credibilty.
- The Developer cares about Completeness.
- The Program Manager cares about Cost.

Achieving all three requires a focus on Composability


Credibility
Information
Requirements
Requirements
Information
Observation & Testing
Modeling & Simulation
Abstraction
Repeated VV&A Process
Abstraction
Single, Unified Abstraction

Completeness Comes in Phases:

- Inception - “Do an easy one”. Demonstrate the concept/value using well understood subset. Plan the full development and deployment life-cycle.
- Elaboration - “Do the hardest one”. Shakedown the concept by prototyping those portions of the product with the highest combination of difficulty, importance, and frequency. Re-plan based on lessons learned.
- Construction - “Do the real one”. Build the baseline product using validated requirements and technologies. Re-plan based on production data.
- Employment - “Use the real one”. Support the product from soup-to-nuts. Re-plan based on operational usage.

Composability:
-- Effective Solutions Require

- Schema for representing Schema's
- Lexicon for naming key domain concepts
- Ontology or taxonomy for domain relationships
- Enumerations for identifying individual instances
- Tools and utilities that make it faster, easier, cheaper to use the integrate solution than to go your own way

Mission-Based Task Standards

Standards express the degree to which (how well) a military organization or force must perform a task* under a specified set of conditions.

A criterion defines acceptable levels of performance for a measure and is often expressed as a minimum acceptable level of performance.

Standard:

Criterion	Scale	Measure
100	km x km	sector search area
5	minute	sector search time
90	percent	probability of detecting threat
1	percent	false alarm rate

***e.g.;** Collect Information on Operational Situation (OP2.2.1)

Stating the Problem "the same old Physical Capabilities way"

Mission:
- **Main Battle Tank closes with and destroys enemy**

Key Performance Parameter:
- **90% probability of kill at 5000 meters.**

Will inevitably constrain the range of solutions to " the same old… "
Monolithic Single-Platform, Mechanically-Integrated Physical Hunter-Killer

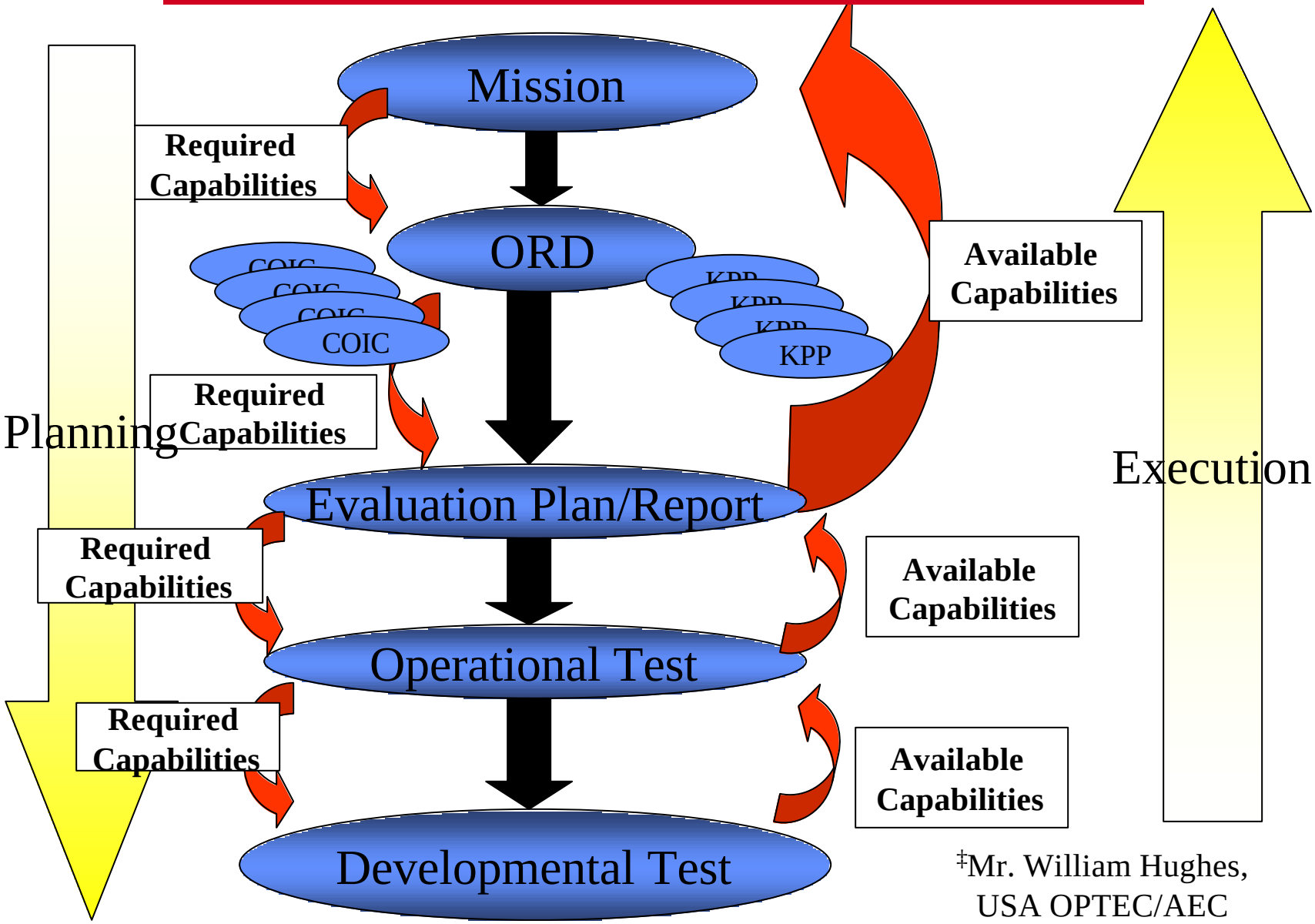
Stating the Problem "the emerging Mission Capabilities way"

Mission:
- **FCS halts OPFOR advance by drawing the enemy into the open for destruction by an affordable combination of direct and indirect fires.**

Key Performance Parameter:
- **Prevent OPFOR firing platform closure to lethal firing positions on manned FCS platforms using awareness, stealth, mobility, and fire.**

Will open the range of solutions to consider " the emerging… "
Distributed Multi-Platform, Digitally-Integrated Virtual Hunter-Killer"

Coordinated Approach to Acquisition‡



‡Mr. William Hughes, USA OPTEC/AEC